VIEW OF SECTION AT SWADLINCOTE.

THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

Quod si cui mortalium cordi et curæ sit non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant. —*Novum Organum, Præfatio.*

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ERRATA ET CORRIGENDA.

Proc., page 48, line 12 from bottom, *after* "composed" *insert* "of."

Page 182, line 6, *for* "anges" *read* "changes."

Page 220, last line, *for* "R" *read* "a."

Page 229, line 21, *for* "skulls" *read* "shells."

Page 238, fig. 4, *twelve* marginals shown ; there should be only *eleven* on each side.

Page 310, line 24 from bottom, *after* "that" *read* "the."

Page 546, in index to Map, symbols of Kimeridge Clay and Corallian transposed.

Page 571, line 10 from bottom, for "RICHMONDIENSE" read "RICHMONDIENSIS.

THE

QUARTERLY JOURNAL

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Vol. XLV.

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1. *The* Permian Rocks *of the* Leicestershire Coal-field.

By Horace T. Brown, Esq., F.G.S., F.I.C. (Read Nov. 7, 1888.)

[Plate I.]

Contents.

(1) Stratigraphical.

The exposed Carboniferous strata of the Leicestershire Coal-field are bounded on their western edge by a narrow strip of coarse current-bedded sandstones and conglomerates, which form the base of the Trias in this part of the country, and which are doubtless homotaxial with the typical Bunter Conglomerate of South Staffordshire, Shropshire, and Cheshire. These sandstones and conglomerates are about 120 feet in thickness on the extreme margin of the Coal-field, but when traced eastward for two or three miles, by the aid of several small outliers, they are found to thin out rapidly, and,

east of a line drawn north and south through Ingleby and Measham, are conformably overlapped by the Lower Keuper *.

The Trias, throughout the greater part of the area, rests upon the truncated edges of Carboniferous rocks, either upon Coal-measures, or, in the northern part of the district, upon Millstone Grit or even Yoredale Shales; there are, however, found here and there, intercalated between the Bunter and the Carboniferous, some thin beds of *purple marls, breccias, and sandstones*, seldom exceeding in aggregate thickness 30 or 40 feet, but differing remarkably, in lithological characters, from both the overlying and the underlying rocks.

My attention was first seriously directed to these rocks during a re-survey, on the six-inch scale, of a tract of country lying immediately to the east of Burton-on-Trent, and the results obtained induced me to make a careful examination of the beds throughout the Coal-field; for, although described and mapped as Permian by the Survey geologists, doubts have been from time to time expressed by various observers as to the true stratigraphical relations of these somewhat obscure rocks.

About the true relation of this brecciated series to the Carboniferous there cannot be the slightest doubt; for when its various members are traced for a little distance along their line of strike they are found to repose successively on Carboniferous strata belonging to very different horizons. This well-marked unconformity has been referred to by Professor Hull in his Survey Memoir, and, so far as I know, only one geologist, the late Mr. W. Molyneux, F.G.S., has attempted to link the brecciated series with the Carboniferous System.

In his 'Burton on Trent, its History and its Waters,' Mr. Molyneux regards these rocks as Upper Coal-measures, and correlates them with the breccias and clays of the upper division of the Coal-measures of North and certain parts of South Staffordshire. He bases this opinion, in the first place, upon a fancied lithological resemblance between the beds of the two districts, and, secondly, upon the supposed fact that the breccias of the Leicestershire Coal-field do not appear "in any section beneath the highest known workable seams of coal of the Ashby Coal-field" (*op. cit.* p. 153). This statement certainly does not bear close examination; for besides being lithologically very dissimilar to the Upper Coal-measure breccias of the North-Staffordshire Coal-field, which are well shown in the neighbourhood of Stoke-on-Trent, these brecciated rocks of the Lei-

* The disappearance of the Bunter eastwards was first noticed by Prof. Hull, and is mentioned at p. 61 of the Memoir on the Geology of the Leicestershire Coal-field. As we have not the slightest evidence of any unconformity between the Bunter and the Keuper in this part of the country, the thinning-out of the former, and its complete overlap by the Lower Keuper, can only be satisfactorily explained by assuming the proximity of an old coast-line of early Triassic times, or, if we accept the views of Prof. Bonney as to the origin of the Bunter, of a portion of the left bank of that great northern river which brought down, from beyond the Scottish border, the rounded pebbles of the Middle Bunter.

cestershire Coal-field *rest with the most striking unconformity upon the true Coal-measures.* In proof of this, I will mention the following facts:—At Brizlincote the breccias rest upon the "Well" coal, whilst, when followed along their line of strike for a distance of only 2000 yards further south, they are found, at the Newhall Park Colliery, in contact with the Nether Main Coal, having consequently overlapped the Coal-measures in this short distance through a vertical thickness of 450 feet. Again, only $2\frac{1}{4}$ miles east of Newhall Park, at Swadlincote, the breccias immediately overlie almost the highest known coals of the district, occurring at a horizon 861 feet above the Main Coal. So that within a very small area the brecciated series occurs in contact with Coal-measures separated from each other by a vertical distance of over 1300 feet, almost the entire thickness of the productive portion of the Coal-field. If any further proof of unconformity were necessary, it is afforded by the detailed sections to be referred to later on, and by the fact that the great Boothorpe fault, which traverses the Coal-field in a N.N.W. and S.S.E. direction, whilst dislocating the Coal-measures near Woodville to the extent of at least 1000 feet, affects the overlying brecciated series at the most 20 or 30 feet. There cannot, therefore, be the slightest doubt that the view expressed by Professor Hull (Survey Memoir, p. 57) that these strata "do not form part of the coal-formation, but are of more recent origin," is the correct one.

On the other hand their relation to the overlying Bunter Conglomerates is not at first sight quite clear.

It has been noted that the Bunter Conglomerates do not occur east of a line drawn from Measham to Ingleby; the brecciated series, however, does occur in one or two spots east of this line, and in these cases is succeeded upwards by the Lower Keuper Sandstone. From the fact of this eastward overlap by higher beds of the Trias, Prof. Hull concludes (Survey Memoir, p. 58) that the breccias do not belong to this latter formation, and doubtfully refers them to the Permian.

This evidence is, however, no absolute proof in itself of the existence of a stratigraphical break, amounting to an unconformity, between the brecciated series and the Trias; for we must bear in mind that we are in close proximity to an old shore-line, which we know gradually receded eastward during subsidence of the old Carboniferous land: hence it seemed to me by no means improbable that the breccias might, after all, belong to the base of the Trias, and represent marginal deposits which swept up the sides of the gradually submerged land, bearing the same relation to the several divisions of the Trias in this part of the country as the Dolomitic Conglomerate of Gloucestershire and the neighbourhood of the Mendips bears to that of the south-west of England *.

This appeared to me to be an alternative and by no means improbable explanation of the facts as known until recently; but I have, within the last few years, been able to accumulate a mass of evidence

* The Keuper breccias at Thringstone, on the borders of Charnwood Forest, are undoubtedly marginal deposits of this kind. They are composed of angular fragments derived from the adjacent Forest-rocks.

which leaves no doubt that Professor Hull's surmise as to the Permian age of at least some of these beds is quite correct.

Whilst engaged in mapping the Coal-measures and overlying rocks on the north-western boundary of the Coal-field between Bretby and Gresley, I obtained many indications of the brecciated series cropping out at the base of the Trias. These small patches were, for the most part, discovered by the constant use of a small hand-borer, consisting of a light jointed steel rod, armed at the end with an auger about $\frac{3}{4}$ inch in diameter.

The surface appearances very often afford no indications of the existence of the breccias and their associated rocks; but by adopting this method, which is easily and rapidly carried out in the field if one has a little assistance, I have been able to discover the existence of the rocks in question in many places hitherto unsuspected, and to delineate their boundaries with absolute accuracy on a large scale map.

In tracing the beds by these means from north to south, I have found the intercalation of the breccias between the Trias and the Carboniferous so extremely uncertain, and their more or less complete overlap by the Bunter so frequent and abrupt, that the facts are not capable of being satisfactorily explained by anything short of an unconformity between the brecciated series and the Bunter.

Better proof of this unconformity is afforded by certain sections which are to be seen on the western boundary of the visible coal-field, at the Newhall Park Colliery, about one mile north of Gresley station *.

Here, in a railway-cutting about 150 yards in length, running in a direction approximately E.S.E. and W.N.W., the Nether Main Coal comes into view near the colliery-shaft, with an apparent easterly dip of 13°. The coal-seam does not quite reach the surface, but is cut off by a fault with a downthrow of 36 feet to the west, thus causing a repetition of the coal outcrop about 70 yards further west. At this point the Nether Coal is covered with a few feet of brightly coloured and strongly variegated red, yellow, and white clays, rapidly giving place, further west, to a bed of *dull red breccia.* This breccia consists of large and small angular and subangular fragments of rock, imbedded in a red calcareous matrix. In places it is consolidated, but near the surface forms a loose rubbly mass showing little or no signs of stratification.

The following sketch (fig. 1) indicates the position of the beds on the south side of the cutting. On the opposite side of the railway the breccias are to be seen resting, apparently horizontally, upon an eroded surface of light-coloured Coal-measure clay which appears to dip 13° E.S.E. The line of junction of the two series of beds is marked by a thin band of coal-smut, the triturated remains of a portion of the Nether Coal which cropped out at this spot on the old Permian beach.

In the underground workings of the colliery the breccias were

* The beds here described do not appear in our one-inch Survey map.

struck, whilst driving a heading, at a depth of 70 ft. from the surface, and about 700 ft. south-west from the mouth of the shaft. This is as nearly as possible the position they ought to occupy from the surface indications, their true dip being 10° due S.

In the pit-section the breccias exactly resemble those of the surface except in colour, the matrix of the former being bluish-grey variegated with a little red, whilst that of the latter is a dull red throughout. This is merely a question of weathering, and the difference is extremely well shown in the Swadlincote section presently to be described. The iron, in the freshly cut and unweathered surfaces, is mainly in the *ferrous* state and becomes oxidized on exposure.

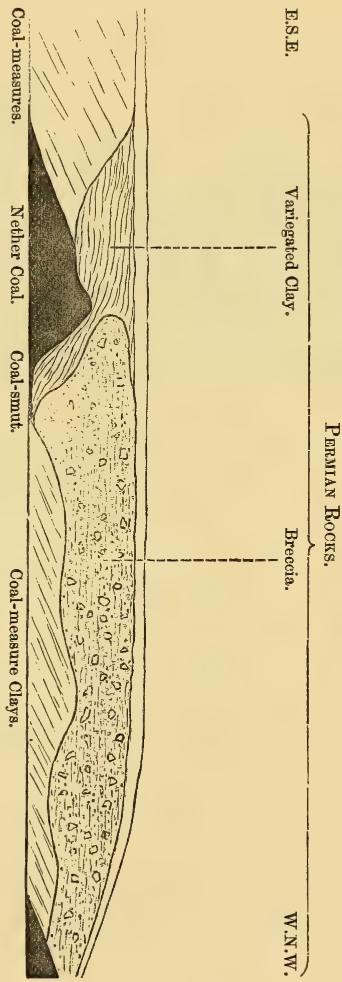


Fig. 1.—*Section on South side of Railway, Newhall Park Colliery.* (Horizontal scale 54 feet=1 inch; vertical scale 18 feet=1 inch.)

Although the Bunter Conglomerates are seen to overlie the breccias of Newhall Park a few yards south of the railway-section, the actual line of junction has not been laid bare. The Bunter has a dip of 7° to 10° S. 63° W.; we consequently have the three series of rocks, in sections within a few yards of each other, showing the following angles and directions of dip, sufficiently indicating a double unconformity:—

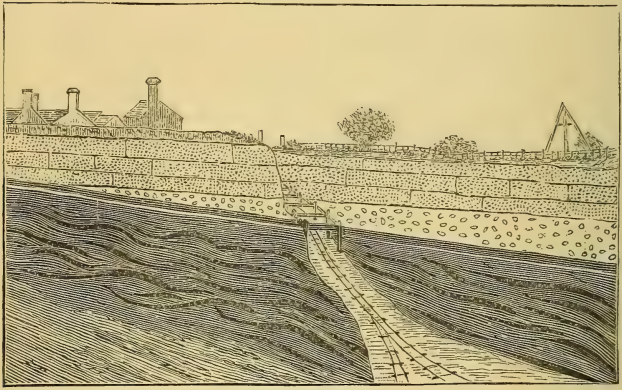
Bunter Conglomerate 7° to 10° S. 63° W.
(Permian) Breccias 10° S.
Coal-measures 15° S. 26° E.

In the neighbourhood of Swadlincote and Woodville two sections have recently been opened out which must completely set at rest any doubts which may still be entertained as to the true stratigraphical position of the brecciated series *.

* These breccias, which are known to the workmen as "Grout," are not indicated on our one-inch Survey maps of the district.

The first which I shall describe occurs at the Boothorpe Sanitary Pipe Works at Woodville, 500 yards S.W. of the Waterworks tower. The details of the section are as follows (see fig. 2):—

Fig. 2.—*Section at Boothorpe Clay Works, Woodville.*



		ft.	in.	ft.	in.
Bunter............	Coarse Sandstone and Conglomerate, with a few clay-partings (c)..........................	10	0		
Permian	Breccia—Fragments of quartzite, fine grit, slate, &c., in a bluish-grey calcareous matrix (b)	0	0 to	3	0
	Grey Marl with occasional seams of very small pebbles	1	0		
	Red and variegated Marls (b').....................	3	0		
Coal-measures...	Highly disturbed purple and grey mottled Clay (a)	3	0		

The Coal-measure clays at the base of this section are highly disturbed and exhibit a very strongly marked slickensided appearance, doubtless produced by the forces which brought about the great Boothorpe fault, which passes within 100 yards of this exposure and throws the Coal-measures to the extent of at least 1000 ft.

The red and grey marls and breccias, which follow in upward order, rest upon an uneven floor of Coal-measure clays, and dip * 5° S., whilst the evenly bedded Bunter Sandstones and Conglomerates overlying them have a dip of only 4° S. In consequence of this the Bunter, as the northern end of the section is reached, gradually oversteps the truncated edges of the overlying brecciated series until it rests directly on the Coal-measures.

A careful examination of the exposure renders it perfectly certain that the brecciated series must have been subjected to very consider-

* A short distance south of this section the beds have a regular dip to the N.E.

able denudation prior to the deposition of the Bunter, and that the phenomena cannot be explained by contemporaneous erosion. This section, in fact, exhibits in a very beautiful manner a double unconformity, and clearly proves that we may without doubt refer the series of strata to which the Breccias belong to the *Permian*; for they are not stratigraphically connected either with the Carboniferous or with the Trias.

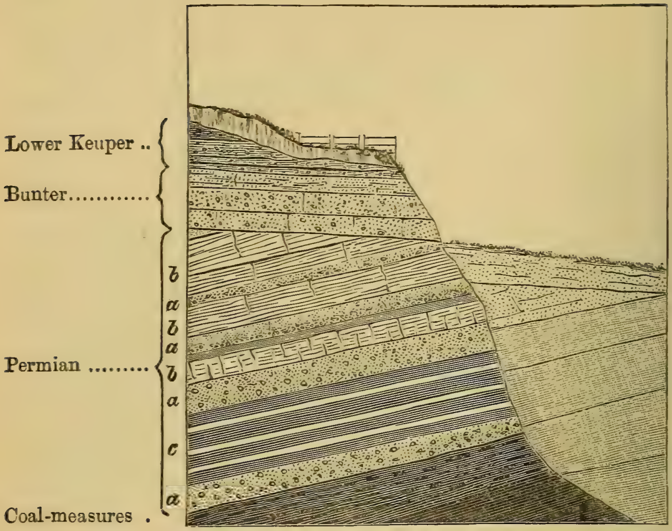
Swadlincote (fig. 3 and Pl. I.).—The stratigraphical break between the Permians of the Leicestershire Coal-field and the Trias is still more strikingly evidenced by an exposure in an open-working at Swadlincote, about 1 mile north-west of the section last described. The pit has been excavated for the purpose of procuring fire-clay, and is 750 yards south-east of Swadlincote Station. This is the exposure referred to by Mr. W. S. Gresley, F.G.S., in his paper "On the Occurrence of Fossiliferous Hæmatite Nodules in the Permian Breccia of Leicestershire" ('Midland Naturalist,' vol. ix. 1886).

The ridge of ground on the side of which the pit is situated is correctly shown on the one-inch Survey maps as an outlier of Bunter Conglomerate. The magnificent section is from 70 to 80 ft. in height, and shows about 8 ft. of horizontally bedded Bunter Conglomerates of the usual type of the district, resting upon about 26 ft. of Permian beds made up of sandstones, breccias, and marls. The Permians, together with the underlying Coal-measure clays and their associated coal-seams, dip into the side of the hill at an angle of 23°, in a direction N. 50° E., so that the unconformity between the Trias and the underlying beds is most striking.

That there is any great break between the Coal-measures and the Permian in this section is not very apparent at first sight, as both seem to dip at the same angle of 23°; but since the section is almost along the line of strike it is possible that there may be a little discordance of dip which is not evident in the present state of the excavation. The unconformity in this case is, however, indicated clearly by the abrupt change in the lithological characters of the beds and by the occurrence at the line of junction of an eroded and impersistent bed of hard, fine-grained, Coal-measure sandstone ("cank").

The following are details of the section as taken in July, 1886; but since that time the face of the excavation has been carried some yards further into the hill, thus exposing a considerable thickness of Lower Keuper Sandstones and Marls above the Bunter Conglomerate, besides showing a considerably greater thickness of Permian and rendering still more evident the distinct break between this series of rocks and the Coal-measures.

Fig. 3.—*Section at Swadlincote**.



a. Breccias. *b.* Buff-coloured Sandstones. *c.* Red and white marls.

		ft. in.	ft. in.
Bunter............ ft. in. ft. in. 5 0 to 8 0	Soil and disturbed ground.	4 0	
	Pebbly Conglomerate with a few thin beds of coarse sandstone	5 0	to 8 0
Permian .... ft. in. ft. in. 26 6 to 27 6	Sandstone, soft and light buff-colour	4 0	to 0 0
	Red and Grey Clay, becoming sandy upwards.	1 6	
	Sandstone, grey, tinged with red; evenly bedded, fissile and beautifully ripple-marked.	3 3	
	Light clay parting	0 3	
	Breccia; divided in middle by 1½ in. clay and sand parting	3 2	
	Sandstone with clay parting. Contains small angular fragments of rock	0 8	
	Red Clay with 3½ in. band of fine breccia, 3 ft. from top	11 0	
	Grey argillaceous Sand, with a few small angular pebbles passing into	0 8	
	Breccia with a very hard ferruginous "cank" stone at base. This "cank" stone is eroded and impersistent	2 0	to 3 0
Coal-measures.	Dark purple and variegated Clays containing large nodules of hæmatite of various degrees of purity	6 0	
	Black pyritous Shales	3 0	
	Coal	1 5	
	Fire-clay.................................. (about)	15 3	
	Coal	1 0	
	Fire-clay.................................. (about)	8 0	
	Coal		
	Fire-clay		

* Fig. 3 represents this section as it appeared in 1887; and Plate I. is a reproduction of a photograph taken in the same open working in the spring of 1888.

About 500 yards east of the section last described is another exposure of the Permians and overlying Bunter. It occurs in an old brickyard by the roadside, opposite Sharpswood Farm. The details are as follows :—

Section in Brickyard near Sharpswood Farm.

		ft. in.	ft. in.
Bunter............ ft. in. ft. in. 3 5 to 4 5	Sandy Clays and coarse Sandstone............	2 0	to 3 0
	Conglomerate (quartzose) with clay galls, in part current-bedded	1 5	
Permian .... ft. in. 22 10	Grey argillaceous Sand..........................	0 8	
	Indurated Red Marl..............................	1 5	
	Fine Breccia	0 3	
	Red and variegated Marl with sandy streak near top	1 7	
	Breccia with a thin argillaceous parting ...	3 11	
	Red and variegated Clays with thin bands of fine whitish sandstone	12 0 (about)	
	Breccia	3 0 (about)	

The above section is the one referred to at page 59 of the Survey Memoir on the Leicestershire Coal-field. The upper portion is there correctly referred to the base of the New Red Sandstone, but Professor Hull was disposed to look upon the Marls and Breccias as Upper Coal-measures. On a later visit to the spot in company with Sir A. Ramsay and the late Rev. W. H. Coleman he came to the conclusion that they must be referred to a newer date, but whether to the Permian or Trias was left uncertain. They were, however, mapped as Permian, and as the beds in question are undoubtedly a lateral extension of those of the Swadlincote open-work, a few hundred yards to the west, we now know this classification to be correct.

In the recent sinking of a shallow well in this brickyard the thickness of the Permian has been proved to be about the same as that of Swadlincote, but the Coal-measures upon which the newer rocks lie in the two sections are of an entirely different character. At Swadlincote they are purple and variegated clays, followed in downward succession by pyritous shales with Coal-seams; whilst in the brickyard the Coal-measures, consisting of hard, grey and blue "bind," with plant-remains, belong to a very much lower horizon. This is accounted for by the fact that the Boothorpe Fault passes between the two exposures, a great line of fracture which throws the Coal-measures down on the west to the extent of at least 1000 feet, whilst it scarcely affects the overlying rocks of later age *.

* Besides the great Post-Carboniferous and Pre-Permian movement along this fault, we have evidence of at least two minor dislocations occurring along the same line, the one of Post-Permian and Pre-Triassic age and the other Post-Triassic. The evidence for the first of these is to be found in the disturbed state of the Permians at the Swadlincote open-work, where they are found dipping towards the fault at a high angle, whilst the Bunter Conglomerates lie in a perfectly undisturbed state across their basset edges.

The Post-Triassic movement along the same line is clearly shown at the Boothorpe Clay Works, where the Permian and Trias are both thrown to the extent of from 20 to 30 feet.

Before describing more minutely the lithological characters of the beds occurring in the three sections just referred to, it will be necessary briefly to call attention to the other localities within the area of the Coal-field in which the Permian beds either crop out at the surface, or have been penetrated in colliery-sinkings.

At the Boothorpe Clay Works the Permian rocks, with the overlying Bunter Conglomerate, have been thrown out by the Boothorpe Fault, on the east side of which we find Coal-measures again brought to the surface for a distance of about half a mile. At the Blackfordby Mine we are on the western edge of a large outlier of New Red Sandstone, which occupies the centre of the coal-field; and we find, exposed in the shaft of the mine, a few feet of Permian breccias and marls similar in character to those occurring at the Boothorpe Clay Works; whilst in the Waterworks well, about $\frac{1}{4}$ mile N.N.W., thin representatives of the same beds have been found *. At this point the Bunter Conglomerate, which thins out rapidly eastward, is only a few feet thick, and a little further to the south-east, at the village of Blackfordby, it has completely died out, and we find the Lower Keuper resting directly on the Coal-measures.

On tracing the margin of the central outlier of New Red Sandstone from this point nearly to Ashby, making frequent use of the boring-rod, I have failed to discover any traces of the Permian beds beneath the Lower Keuper.

Ashby.—At p. 60 of the Survey Memoir reference is made to a small exposure of sandstone and marls in the railway-cutting on the west side of Ashby Station. Although mapped as Trias, the age of these beds was considered doubtful by the geologists of the Survey. The slopes of the cutting are now much obscured by vegetation; but by repeated trial-borings in the banks the beds in question were at last discovered, 330 yds. west of the railway goods-shed. They consist of 2 or 3 feet of sandstone, resting on purple marls, which in turn are succeeded downwards by Coal-measure clays. The sandstone is of a distinctly Lower Keuper type, and does not resemble in any of its characteristics the true Permian sandstones of the district. The underlying marls, which are of a bright purple colour, are only about 18 inches thick. That they belong to the Permian series is rendered probable both by their colour and by the fact that hæmatite nodules have been observed in them. Such fragments of hæmatite are of frequent occurrence in the Permians; but, so far as I know, they never occur in the Triassic marls of the neighbourhood.

Packington.—There are at the village of Packington three small exposures of unconsolidated breccia in a red marly matrix. One of these is opposite the Bull's Head Inn; the second by the roadside 160 yds. north of this point, and the third in a brook-course 160 yds. south-east of the inn. These are the most easterly exposures of the Permian beds which occur within the area of the Leicestershire

* The marls and breccias indicated in fig. 5, p. 35, of the Survey Memoir, as occurring at the outcrop of the Ten-foot Coal at Blackfordby doubtless belong to the Permian and not to the New Red, as there stated. This particular section is, however, now obliterated.

Coal-field. I have been able to ascertain by a series of borings at various points that they are correctly delineated on the Survey Map as being overlain by Lower Keuper, and not by Bunter, as is the case further to the west.

Measham Fields.—A large outcrop of Permian breccia, nearly 1 mile by ¾ mile, is marked in the Survey Map as occurring here. There are no actual exposures of the rock visible at the present time, but I have confirmed the existence of the breccia by a number of borings. The area of this outcrop of Permian is, however, much smaller than appears on the Survey map, where it is shown to extend too far to the north. I have found also that on its western edge it is overlain by coarse pebbly sandstone of the Bunter, and not immediately by Lower Keuper.

Measham.—In an old quarry by the side of the canal, 300 yds. west of the church, is a fine section of the breccia, which is unevenly bedded and highly consolidated. The total thickness exposed is about 13 feet, and the apparent dip 5° W. 30° S.

In a well in Hincks's Close, 320 yds. east of the church, occurs the following section:—

		ft.	in.
	Red Clay	9	0
	Lower Keuper Sandstone	4	0
	Clay-parting ... a few inches.		
Permian. 21 ft. 0 in.	Breccia	3	0
	Red Marl, with brecciated fragments	18	0
	Blue Coal-measure Clay.		

Oakthorpe.—The canal has here been cut through a consolidated breccia exactly similar to that of Measham, and the rock has been used in the construction of the wall which bounds the towing-path. Here again I have found the outcrop of the Permian beds less extensive than the Survey map would lead us to expect.

Indications of an unconsolidated breccia are to be found on the east side of the railway-cutting, between Oakthorpe and Donisthorpe, at a point 25 yds. north of the bridge which spans the railway at Hall Farm.

Overseal.—On following the western edge of the visible Coal-field northward from Overseal, frequent indications of the existence of thin brecciated-beds are met with, resting immediately on the Coal-measures.

Gresley.—Just north of the Castle Hill at Gresley the junction of the breccias and overlying Bunter was visible a few years ago in a sand-pit. This section, which is now obscured, exhibited very clearly the stratigraphical break between the two series of rocks.

Between Gresley Station and Bretby I have found seven small outcrops of Permian, which I have laid down with exactness on the six-inch map, their boundaries having been determined with the boring-rod. The thickness of the beds varies from one or two to 20 feet *.

* The boundary of the Coal-field from a little south of Brizlincote Hall to Oldicote Farm is represented on the Survey map as a *fault*, which apparently cuts out the Bunter Conglomerate and lets down the Lower Keuper against the Coal-

Linton.—Outside the western edge of the visible coal-field we have three localities in which the Permians have been observed. At the village of Linton, about one mile south-west of Gresley Station, the breccias crop out at the surface as shown in the one-inch map; and a few years ago there was exposed a section which is figured at p. 59 of the Survey Memoir. This section is now obliterated, but traces of the breccias of the usual Permian type can still be seen in the private road of the Manor House. The late Rev. W. H. Coleman, in his 'Outlines of the Geology of Leicestershire,' p. 23, states that in a well at Linton 42 ft. 6 in. of Permian were found overlying the Coal-measures.

Netherseal Colliery.—At the Netherseal Colliery *, 1¼ mile west of Overseal, the Trias was found to be 213 feet thick (the Lower Keuper 75 ft. and the Bunter 138 ft.), and between this and the Coal-measures the records of the sinking note the existence of a series of grey sandstones with soft blue partings, and a bed of red marl at the base 7 ft. 10 in. in thickness. The total thickness of these beds, which from their description I have no hesitation in referring to the Permian, is 37 ft. 6 in.; this is in excess of anything I have found further to the east.

Coton Park Colliery.—At the Coton Park Colliery, ⅔ mile west of Gresley Station, about 7 ft. 9 in. of reddish breccia were passed through. This rested upon about 14 ft. of purple marls, which, from the description given to me by Mr. Gresley, I should class as Coal-measures. Mr. Molyneux, at p. 157 of his 'History of Burton-on-Trent,' describes the rocks immediately below the Trias at this point as consisting of 90 ft. of "grits and red and mottled clays (containing Stigmaria and other plant-remains), intersected by breccias resembling those of the Leather Mill section" (Hartshorn Brook). The breccias certainly do not intersect the grits and mottled clays, but overlie them †.

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measures. This interpretation cannot, however, be the correct one, as I have found, on carefully following the line of junction of the Trias and Coal-measures with the boring-rod, that it is so sinuous as utterly to forbid the idea of its being a line of fault. Moreover, a very thin outcrop of Permian occurs 300 yds. west of Geary House, intercalated between the Lower Keuper and the Coal-measures. The underground workings in the adjoining collieries also agree with the surface-indications, and prove the unbroken continuity of the Coal-measures between the Bretby Collieries and the disused Anglesea Pit, south of Moat Bank.

The absence of the Bunter here is consequently not due to the faulting, but to an *overlap* of Lower Keuper. We have indications, however, both to the east and to the west, of the occurrence of Bunter Conglomerate, in the latter case in sinkings, and in the former in the small outlier of Conglomerate resting on the Coal-measures at Bretby Colliery. Consequently we have a small area near Brizlincote Hall which cannot have been submerged in Triassic times until a period later than the deposition of the Bunter. This small patch of Carboniferous land must either have been a promontory stretching westward from the mainland, or, what is more likely, a small *island* close to the shore, which did not become completely submerged until after the deposition of the greater part of the Lower Keuper Sandstones of the neighbourhood.

* I am indebted to Mr. E. Hague for this information.

† The section given at p. 261 of Mr. Molyneux's work, which is headed "Section of Strata passed through at the Coton Park Colliery," evidently refers

A little west of the Decoy Wood at Bretby occurs a fault running in a south south-easterly direction, with a downthrow to the east, and bringing down the Triassic rocks against the Coal-measures, thus forming the boundary of the Coal-field for the distance of about a mile. This is the Moira Main Fault, which has been proved between Newhall and Bretby to throw the Coal-measures to the extent of 240 ft. Like all the other great lines of fracture of this district which run in a direction approximately N.N.W. and S.S.E., the principal movement occurred in Pre-Permian times; but considerable movement has also taken place along this particular fault in Post-Triassic times, and has resulted in the natural boundary of the Trias and Coal-measures being moved considerably to the south-east, the general direction of dip of the upper measures being about N.W.

Hartshorn.—About one mile north-west of the village of Hartshorn the junction of the Trias and Coal-measures is again one of ordinary superposition, and the Survey map indicates the existence of a V-shaped patch of Permian of considerable extent, skirting the base of the Conglomerate hills, and stretching from Ley Wood Hill on the west, and Caulkley Wood on the east, with the point of the V extending down the valley of the Hartshorn brook as far as Bretby Mill. The Survey Memoir (p. 58) refers to these exposures as consisting of loose breccias and marls, but states that "not much faith is to be put in the Permian age of these beds." Mr. Molyneux, in his 'History of Burton-on-Trent,' p. 153, gives a very confused account of both their appearance and stratigraphical position; and whilst referring them to Upper Coal-measures, describes as Permian certain overlying sandstones which are undoubtedly Triassic. My own observations in this locality are as follows:—

At Glover's Mill the Bunter Conglomerate of Moxon's Hill rests directly upon Coal-measures, as was proved by running a line of borings down the eastern slope of the hill towards the brook; but on following the line of junction northwards for about 250 yds. a bed of purple marl was found insinuating itself as a wedge-shaped outcrop between the Bunter and the Carboniferous. A little further north, at Hoofies Wood, this bed of marl has gradually thickened to about 20 ft., and is well exposed in a small marl-pit on the eastern side of the wood, near the little bridge. Here are seen from 12 to 15 ft. of deep purple marls, with some light-yellow, sandy bands of from 1½ to 2 inches in thickness. About the middle of the section is a thin bed of consolidated breccia of from 8 to 9 inches.

A few hundred yards further down the brook, about 30 yds. south-west of Bugley Cottage, there can be seen, in the banks, unconsolidated breccias and red and variegated clays overlying Coal-measure shales.

These beds of the Hartshorn brook, both from their stratigraphical position and their lithological characters, may with the greatest

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to the sinking which is now known as the "Netherseal Colliery," and which originally was named the "Coton Park," and afterwards the "West Moira" pit. Here, again, beds which we now know to be Permian have been classed erroneously with the Coal-measures.

certainty be correlated with the Permians of other parts of the Coal-field. Their northerly extension cannot, however, be traced further down the brook-course than Bugley Cottage, where the Conglomerates again rest directly on the Coal-measures.

Following the sweep of the Bunter hills round Caulkley Wood, there are again found traces of red marls overlying the Coal-measures on the south-east side of the wood, and at a small spring in the southern angle of the enclosure are indications of red marls associated with a few thin beds of a very soft, buff-coloured sandstone, exactly similar to the highly characteristic Permian sandstone of the Swadlincote open-work section.

A little east of Caulkley Wood the Millstone Grit rises from beneath the Lower Coal-measures of the northern parts of the Coal-field, and from Brick House to Knowle Hills the boundary between the Bunter Conglomerate and the Grit is represented on the Survey map as a fault, having a general direction N.N.E. A careful and prolonged study of this part of the district has convinced me that the supposed fault has no existence.

From Caulkley Wood to the south side of Gravel-pit Hill the Bunter was proved by boring to rest directly on Coal-measures. A little south of Brick House the Bunter sweeps round the hill to the north, and at this point red Permian Marls with light sandy seams appear at its base, and gradually thicken northward, until, under Bondwood Farm, on the slopes overlooking Repton Rocks, they attain a thickness of about 60 feet. There are no exposures of these beds, but I have satisfied myself, by borings conducted at very short intervals down the slopes, that they do not contain any brecciated bands, whilst at the same time they resemble in every other particular the Permian Marls further south. Perhaps no other part of the Coal-field, where actual exposures are absent, affords better evidence than this of the enormous stratigraphical break between the Permian and Carboniferous; for the Marls, which are in contact with Coal-measures at Gravel-pit Hill, are found a few hundred yards to the north resting upon Millstone Grit, the strike of one set of beds being almost at right angles to that of the other.

Repton Rocks.—The natural excavation in the Millstone Grit, known as Repton Rocks or Dawson's Rocks, forms a *cul-de-sac*, at the head of a deep little valley, cut out by a small stream which takes its course northwards into the Trent. The Grit is lost sight of near a narrow opening at the north end of the *cul-de-sac*, the valley lower down being excavated in the Bunter Conglomerate. It is through this point that the supposed fault of the Survey map passes; but since I have found Trias and Permian mantling round the northern extension of the Millstone-Grit outcrop, and occupying ground which ought to consist of Grit, it is very evident that no such fault exists.

Milton.—The small stream which runs northward from Repton Rocks to Milton is fed by strong springs issuing from the base of Bunter Conglomerate, which appears to have been cut through almost to the underlying rocks. At one spot in the valley, near a

small barn, 170 yards south of the fish-pond under Little Orange Hill, the old floor of the Trias has been laid bare in a small excavation made for the purpose of obtaining clay. It consists of Millstone Grit *, and between it and the Bunter are to be seen traces of purple and white variegated clay, with a little soft greenish sandstone resembling that of Caulkley Hill. The beds are not more than 18 inches thick, but are sufficiently developed to be recognizable as attenuated representatives of the Permian marls which occur, 60 feet thick, about a mile further south.

Sweeping round the northern and eastern sides of Repton Rocks the boundary of the Trias and Carboniferous bends once more northwards and passing near Foremark Park reaches as far to the east as Ticknall church, thus encroaching for a distance of about half a mile into the area coloured on the Survey map as Millstone Grit and Carboniferous Limestone Shale †. Owing to a covering of drift along part of this line, it is difficult to conduct boring-operations with success; but, so far as I have been able to ascertain, the Trias rests directly on the Carboniferous rocks.

Ingleby and Knowle Hills.—Between the village of Ingleby and Knowle Hills lies a small tract of country, the structure of which appears to have been very erroneously interpreted by the geologists of the Survey. At p. 58 of the Survey Memoir we find the following description of this part:—"A small district composed of red-coloured strata extends from the village of Ingleby to the Knowl Hills, near Foremark Park. A line of cliffs formed of the light-coloured sandstone and conglomerate of the New Red formation rises above the alluvial plain of the Trent, and at Ingleby red marls, streaked with bands of white, may be seen cropping out from underneath these sandstone cliffs. We can trace these marls for some distance eastward, but at Knowl Hills, some beds of sandstone, differing considerably in mineral characters from those of the Trias, are found to intervene between these latter and the red marls. It would, therefore, appear that between this locality and Ingleby the New Red Sandstone had overlapped unconformably the red sandstones which form the Knowl Hills; from which circumstance, taken in conjunction with their lithological character, it is probable that the latter are of Permian date."

In accordance with this description, we find that the patch of Coal-measures to the east of Ingleby is indicated as not being overlain directly by the Bunter, but that between these two series of rocks there is a narrow strip of Permian running southward from Ingleby to a little beyond Knowle Hills, and that at Coppy Hill this strip suddenly widens out to a breadth of nearly half a mile.

The rocks of Knowle Hills are further described as consisting of

* Both here and at Repton Rocks we have strong indications of the uneven and eroded nature of the old Carboniferous floor upon which the Permian and Triassic sediments were deposited.

† On a careful re-survey of the Trias in this part of the country it will be found that considerable tracts which have been mapped as Bunter Conglomerate should have been included with the Lower Keuper.

"fine-grained red and brown sandstones regularly bedded, containing no pebbles, and occasionally parted by seams of marl."

Suspicions were aroused in my mind as to the true Permian age of these Knowle-Hills sandstones on my earliest acquaintance with them; for whilst they are described in the Memoir as differing in general appearance from the sandstones of the Trias, I found, as a matter of fact, that it was absolutely impossible to distinguish them lithologically from certain Triassic sandstones which I discovered in the immediate neighbourhood actually *overlying* the Bunter Conglomerate. The difficulty in the way of regarding these sandstones as Permian was much increased as I became more intimately acquainted with the true Permian of the whole district; and it is evident, if Professor Hull's view of their age is correct, that we must make the assumption that beds which present certain uniform characters throughout the whole area of the coal-field, and for many miles to the south, suddenly, and without any apparent transition, entirely change their facies within a distance of less than two miles. Although this assumption seemed an improbable one to make, nothing short of a careful re-survey of the neighbourhood could settle the matter beyond all doubt. This I have now accomplished, with the result indicated in the accompanying map (fig. 4), which has been reduced from one on the six-inch scale.

There are a considerable number of natural exposures within the area, but the information obtained from them was supplemented by numerous borings, which enable me to claim a degree of accuracy for the map which would have been otherwise unattainable.

It will be seen, from the map and section, that the area including Knowle Hill and Coppy Hill, within which occur the so-called Permian sandstones, really consists of an outcrop of Lower Keuper overlying Bunter Conglomerate, and that the beds owe their present position to the existence of a *trough-fault*, which has let them down on the east against Coal-measures and Permian Marls, and on the south-west against the last-mentioned beds and Bunter Conglomerate.

The intersection of the two arms of the trough-fault is at the south end of Robin Wood, one of them running thence towards Ingleby, whilst the other passes in a north-westerly direction through Seven Spouts. Until the existence of these faults was proved, it was natural to suppose that the Knowle-Hills sandstones underlay the Conglomerates, and consequently it was fair to assume that they might be Permian. We now know that they belong to a higher horizon *.

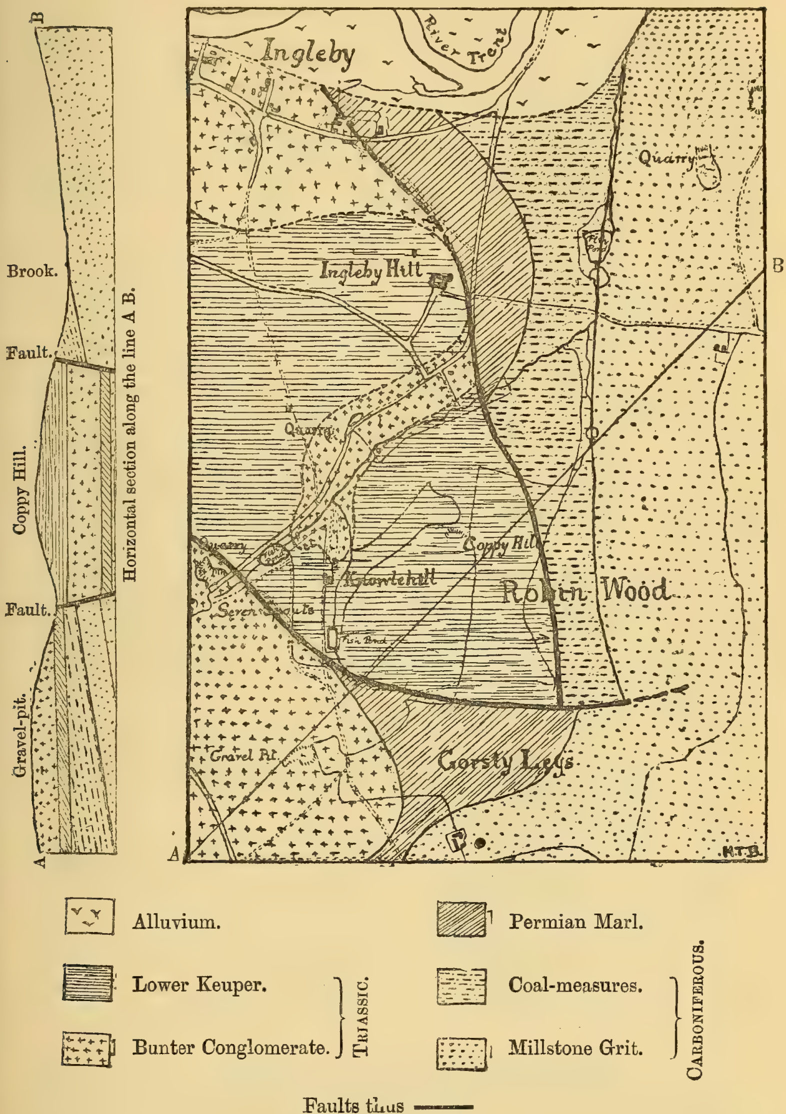
The red marls which occur below the Bunter Conglomerate at Ingleby, and also those of Gorsty Leys, have all the characters of the Permian Marls of the Repton-Rocks district further south, and they are doubtless an extension of the same beds. They contain no brecciated bands †.

* On the slopes south of Ingleby Hills, during the progress of some excavations for water-pipes, I found sandstones similar to those of Knowle Hills overlying the Bunter Conglomerate.

† The small patch of Coal-measures in this district consists of clays and

Fig. 4.—*Map of the Ingleby and Knowle-Hill District.*

(Re-surveyed on the six-inch scale and reduced one half.)



Moira and Boothorpe Grit.—We have now to consider the stratigraphical position of two small patches of sandstone which occur near the centre of the western portion of the Coal-field. These are the so-called Moira and Boothorpe Grits, the true age of which has never been satisfactorily determined. The late Rev. W. H. Coleman, an exceedingly accurate observer and sound geologist, states, in his 'Outline of the Geology of Leicestershire,' p. 25, that whilst the rocks may possibly be referred to the base of the Permian, he is more inclined to look upon them as Upper Coal-measures, unconformable to the lower beds; this view was adopted in the Survey Memoir, the balance of evidence being considered to be in its favour. Notwithstanding this statement, however, the two outcrops of grit are coloured in the one-inch map as *Permian*, but are omitted from the smaller map attached to the Memoir.

There is a small exposure of these sandstones about 860 yards east of Moira Station. They here consist of fissile grits, interstratified with some sandy beds of impure hæmatite containing impressions of *Sternbergia*. About 250 yards further north, in an old quarry between the last-mentioned spot and Norris Hill Lodge, the grits are again exposed, associated with sandy clays. They are in part very coarse and felspathic, and much resemble some of the Millstone Grits of the district. North of this point I have been unable to find, by careful boring, any indications of these grits for some considerable distance, although the Survey map represents them as extending more than half a mile further to the north. At the little hamlet of Boothorpe, however, there is, in an old disused lane, an exposure of massive grits, in parts stained a reddish-purple colour, and evidently belonging approximately to the same horizon as those of Moira further to the south. These Boothorpe Grits occur in a very favourable spot for a determination of their true stratigraphical position, since they crop out immediately to the west of a Triassic outlier whose exact nature and boundaries I have accurately ascertained.

This outlier is represented in the Survey map as a narrow strip of Bunter Conglomerate, extending from a little south of Woodville for a distance of 1¼ mile in a south-south-east direction, and bounded both to the east and west by faults.

From the accompanying map (fig. 5) it will be seen that, whilst its southerly extension is not so great as has been imagined, the Lower Keuper as well as the Bunter Conglomerate are represented in this narrow outlier. The Triassic beds dip E.N.E. about 6°, and are on the east brought down against Coal-measures by secondary movements in the Boothorpe fault, whilst on the west they rest on Coal-measures, with the intercalation, for a short distance, of a narrow strip of

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sandstones belonging to the Lower Coal-measures. Reasons have been given for doubting the existence further south of the extensive fault which, according to the one-inch Survey map, forms the boundary of these Coal-measures and the Millstone Grit on the east. I cannot find any distinct evidence of the existence of a fault between these two subdivisions of the Carboniferous in the Ingleby district.

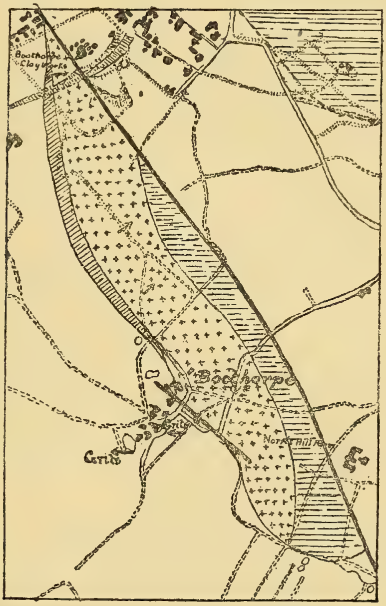
Permian breccia, which is the southerly prolongation of the outcrop occurring at the Boothorpe Clay Works, described in detail earlier in this paper. This narrow Permian outcrop can be traced within a few hundred yards of the Boothorpe Grits, but the dip of the two sets of beds is almost diametrically opposite, that of the grits being 12° to 15° N.W., whilst the Permians and Trias dip 6° E.N.E. Moreover be ween the western edge of the Triassic outlier and the Boothorpe Grits are bluish clays of the ordinary Coal-measure type.

These facts, taken together, absolutely negative the idea of the Boothorpe and Moira Grits being of Permian age: there can be no doubt that they belong to the Coal-measures, but I have failed

Fig. 5.—*Map of country around Boothorpe.*

(Re-surveyed on the six-inch scale and reduced one half.)

Boothorpe Fault.



Permian. Bunter.
Lower Keuper. Coal-measures.

to discover any evidence of their unconformity to the underlying beds. It is, I believe, their anomalous red colour in the neighbourhood of Boothorpe, a colour unusual in Coal-measures, which has led some observers to suspect these grits to be of Permian

age; but this staining can readily be accounted for by the fact that they must have originally been directly overlain by *true Permian breccias* from which the iron-staining has been derived by weathering and percolation of water *.

The position of the Boothorpe and Moira Grits makes it almost certain that they belong to the highest known Coal-measures of the Ashby Coal-field, but nevertheless I am not disposed to regard them as *Upper Coal-measures*. We have, as we shall see later on, the strongest possible evidence that the Coal-measures of the Leicestershire and North Warwickshire districts belong to the same area of deposition, and that the true Upper Coal-measures of Warwickshire, with their associated *Spirorbis Limestone*, which has been traced over an area of about 10,000 square miles, must at one time have spread completely over the Leicestershire Coal-field. All traces of these beds must have been denuded in the Leicestershire district prior to the deposition of the Permian, leaving as the highest surviving representatives the Boothorpe and Moira Grits, which I have found to resemble very closely certain grits of the North Warwickshire area, occurring above the "four-foot coal" at Polesworth.

Windmill Spinney.—There only now remains for consideration a small patch of so-called Upper Coal-measures, which is coloured red on the Survey map, and covers a small area occupied by the rising ground of Windmill Spinney, about $\frac{5}{6}$ mile north-west of Newhall church. From the occurrence of certain fragments of coarse grit, resembling Millstone Grit, on the summit of this hill, it was considered by the geologists of the Survey (Survey Memoir, p. 56) to be an outlier of sandstone resting horizontally, and hence unconformably, upon the inclined Coal-measures below. These sandstones were regarded as being identical with the Moira and Boothorpe Grits described above. A careful examination of the spot has failed to confirm these conclusions; for whilst the boring-rod proved the summit of the ridge to consist of the ordinary sandy clays and shales of the Middle Coal-measures, further evidence of a like character has been recently afforded by a heading driven into the side of the hill. It is perfectly true that fragments of coarse grit are to be found on the hill; but these, I have ascertained, are in no way an index of the underlying rock, but are merely the fragments of the *millstones* from a long-dismantled windmill which once crowned the summit of the ridge. I have called attention to this erroneous observation more fully than I should otherwise have done, since I believe it has been the principal cause of the equally erroneous view that the Moira and Boothorpe Grits are unconformable to the main mass of the Coal-measures; for if these grits had really occurred on Windmill Spinney Hill, as stated, their unconformity would have been beyond all doubt, as in this spot they would have been almost

* Professor Lebour (Geolog. Assoc. Proc. ix. p. 569) mentions the staining of the Coal-measures of some parts of Northumberland by the overlying Permians having led to the erroneous belief at one time that the former represented the Rothtodtliegende.

in contact with the Main Coal, whilst at Boothorpe we know they overlie strata belonging to a very much higher horizon in the Coal-measures.

(2) Lithological Characters of the Beds.

Throughout the whole of the district we are describing, the Permian beds maintain certain well-marked lithological characters, which, apart from any consideration as to the stratigraphical position of the series, are sufficient to differentiate them with certainty from both the Trias and the Carboniferous. At their outcrop they generally yield a subsoil of deep red or purple clay, sometimes sandy, and containing more or less of brecciated fragments *. When observed in freshly cut sections, such as those described above (pp. 6 & 8) as occurring at Swadlincote and the Boothorpe Clay Works, it is seen that the red and purple clays, which are associated, as a rule, with thin white sandy bands and several beds of breccia, occur at the base of the series. The red clays are much more purple in colour and more homogeneous in character than the marls of the Lower Keuper, and are of a decidedly different shade of colour from the marls of the Upper Keuper. The Permian marls with their breccias are, at Swadlincote, followed upwards by a few feet of evenly bedded, fine-grained sandstones, which are fissile and often beautifully ripple-marked. These sandstones are of a light buff colour, as a rule, very soft, and contain numerous specks of a blackish mineral. They are very unlike the sandstones found on any other geological horizon in the district.

The principal interest, however, centres in the *brecciated bands*, which, it will be seen, have yielded a large amount of information throwing light upon the physical changes attending the deposition of the whole series.

The brecciated bands are rarely more than 3 feet in thickness, and contain fragments of a great variety of rock, all comparatively little water-worn, and varying in size from that of a pea to 5 or 6 inches across. Occasionally still larger fragments occur; but as a rule they do not measure more than $1\frac{1}{2}$ to 2 inches along their greatest dimensions.

These angular pieces of rock are imbedded in a bluish-grey matrix of calcareous sand, which varies very much in hardness. Sometimes, as at Measham and Oakthorpe, it forms, with the enclosed fragments, a rock of a considerable degree of hardness, whilst at other places, as Newhall Park Colliery, Swadlincote, &c., it is only in part consolidated, and readily breaks down under the action of the weather.

* The red marly soil at the outcrop of the Permians is of a very rich and fertile character, and affords in this respect a great contrast to the very light, sandy, and pebbly soil of the Bunter, and to the cold, heavy soil of the underlying Coal-measure clays. The Permian marls are in some localities used for "dressing" the sandy soils of the Bunter, which are so light as occasionally to be completely denuded by the action of the wind.

The following is an analysis of the calcareous portion of the matrix from a specimen from Newhall Park*:—

Calcium carbonate	8·51
Magnesium carbonate	5·04
Hydrated ferrous oxide (FeH_2O_2)	3·57
Ferric oxide (Fe_2O_3)	·83
Silica, soluble in dilute HCl	1·12
Insoluble residue	80·93
	100·00

The ferrous salt of the matrix on exposure is oxidized to ferric hydrate, thus causing the whole rock to assume a deep red colour, which stains the exterior of the brecciated fragments.

When a bed of breccia is traced for a short distance horizontally it is never found to be very persistent, but dovetails into sandy and marly beds, just as do many of the beds of breccia in the fine sections at the base of the Trias on the south coast of Devonshire. But although individual beds may die out quickly, their places are taken by other brecciated bands on the same or slightly different horizons; so that the breccia, as a distinct feature in the Permian rocks, may be traced over a considerable portion of the coal-field. There is, however, most undoubtedly a general tendency, when the Permians are traced within the above area from south to north, *for the more brecciated members of the series to die out northward, whilst the marly portions for the most part thicken in that direction.* At Packington, for instance, the breccias are well developed and the fragments are large and angular; whilst four miles to the north-north-west, at Swadlincote, the brecciated bands are thinner and the included fragments somewhat less angular; and about two miles still further to the north, near the Hartshorn brook, we find but very meagre representatives of the breccias, whilst at Repton Rocks, but a mile and a half north-east of this latter spot, the breccias are entirely absent. On the other hand, the marls, of which at Swadlincote there are only 15 feet, at Repton Rocks have thickened out to from 60 to 70 feet. The great importance of these facts will be evident when we come to consider the origin of the sediment which makes up the Permian rocks of the district under consideration.

(3) The Rock-fragments of the Breccias.

The accounts hitherto published of the rock-fragments contained in the Permian breccias of the Leicestershire Coal-field are very incomplete. The Rev. W. H. Coleman, in his 'Outlines of the Geology of Leicestershire' (p. 26), states "that they consist of Silurian and Carboniferous rocks, associated with pebbles of basalt and other Trappean rocks, all of which appear to have travelled from the W., for no fragments referable to the Charnwood rocks are to be found among them." In the Survey Memoir (p. 59) they are

* I am indebted to Mr. J. G. Wells for this analysis.

described as consisting of "light green and indurated slate, grits of various colours and textures, dark brown and purple sandstones, often micaceous; chert, felspar, trap (?), and quartz." At Packington the breccia is stated to be principally composed of slate.

More recently Mr. W. S. Gresley, F.G.S., has published (Proc. Geol. Soc. 1884–85, p. 96, and 'Midland Naturalist,' vol. ix.) a very complete account of certain hæmatite nodules which occur in the breccias of some localities in the district; and he briefly refers to the other fragments associated with the hæmatite as consisting of sandstones of various colours, vein-quartz enclosing greenish slate, quartzite boulders and pebbles, pudding-stone, granitic rocks, red and green clay-slate, igneous rocks, coarse jasper, hornstone, chert, lumps of siliceous and of red, earthy, cone-in-cone formation, and pebbles of indurated clay and slaty rocks.

Professor Bonney examined Mr. Gresley's specimens and gave an account of their microscopical characters in his Presidential Address to Section C of the British Association in 1886. A few of the specimens were found to be distinctly referable to the Charnwood series; but the one which is most fully described is a hard conglomerate, doubtless the "pudding-stone" of Mr. Gresley, which Prof. Bonney considers to be made up of material in part originally derived from the Charnwood series, and in part from volcanic vents of a later age and unknown locality.

The unsatisfactory state of our knowledge of the rock-fragments of the breccias is sufficiently indicated by the somewhat conflicting statements just cited, and it therefore appeared to me that a prolonged and detailed study of these fragments was desirable, and might lead, not only to a certain correlation of the beds with the Permians of surrounding districts, but also to a knowledge of the physical conditions under which these beds were deposited, and of the source from which the sediment was derived. It seemed, in fact, an excellent opportunity of applying the principles laid down in the Address referred to above, and summarized by Prof. Bonney as "the application of microscopic analysis to discovering the physical geography of bygone ages."

I may state that it would have been absolutely impossible for me to have carried this portion of my subject to a successful issue had it not been for the generous and constant assistance of Prof. Bonney, who has, from the outset, taken the greatest possible interest in my work and has at all times placed at my disposal his wide knowledge of rocks and of their microscopical examination. To Prof. Lapworth I am also much indebted for assistance in identifying some of my rock-specimens with those of his own classical district of Nuneaton.

Owing to the possibility of accidentally including rock-specimens from the Drift, if the fragments for systematic study are obtained from the outcrop of the thin band of Permian beds, it is essential that they should be taken from cleanly-cut sections if we are to avoid a source of error from which, I believe, some of the observations of previous workers are not wholly free. This necessary condition limits the choice of localites to the following spots, from each of

which I have collected and examined a very large number of fragments.

(1) Boothorpe Clay Works, Woodville.
(2) Packington.
(3) Newhall Park Colliery.
(4) Measham (section by side of canal).
(5) Hartshorn Brook (near Bugley Cottage).
(6) Polesworth.

The first five localities are all within the area of the Leicestershire Coal-field. The beds from which the fragments of No. 6 were obtained are exposed in a road-section half a mile east of the village of Polesworth, at the north end of the Warwickshire Coal-field. This outcrop of consolidated breccia occurs within six miles of the most southerly exposures of the Permian beds of the Leicestershire Coal-field, and enables us to link these latter with the Permian which is so well developed further south, in the neighbourhood of Coventry and Warwick.

The fragments which most largely predominate in the breccias of the above-mentioned localities are *felspathic grits*, graduating in one direction insensibly into well-defined *felspathic quartzites*, and in the other into gritty, more or less *felspathic, slates*. Besides these we have occasional fragments of *grey flinty slates* and *argillites*, forming with the grits &c. a series of rocks, the members of which hang on to each other, both macroscopically and microscopically, in such a way as to indicate that they have been derived from beds of about the same age.

In addition we often find large pieces of vein-quartz, volcanic ash, and more or less decomposed igneous rocks; also a very variable number of fragments of Lower, Middle, and Upper Carboniferous age.

The following is a numerical analysis of a very large number of fragments from four of the above-mentioned spots. The numbers are expressed in percentages.

		(1). Boothorpe Clay Works.	(2). Packington.	(3). Newhall Park Colliery.	(6). Polesworth.
Old Palæozoic.	Felspathic Grits and Quartzites	75·1	50·8	34·5	84·0
	Gritty Slates	9·7	34·6	11·0	
	Grey flinty Slate	3·2	·8	9·8	2·6
	Argillites	1·1			
	Vein-Quartz	1·6	...	1·2	
	Volcanic Ash	2·2	·8	1·2	
	Igneous Rocks, more or less decomposed	4·4	7·2	13·5	4·0
Carboniferous.	Impure argillaceous Limestone, resembling basement beds of Mountain Limestone	2·2			
	Compact Mountain Limestone	...	...		9·4
	Carboniferous Grits and hæmatite	·5	5·8	28·8	
		100·0	100·0	100·0	100·0

Felspathic Grits or Quartzites.—I have had slices cut for microscopical examination from eight specimens in every way typical of those which are, numerically speaking, by far the most important of the brecciated fragments. Four of these are from the Boothorpe section (Series 1), one from Packington (Series 2), one from Measham (Series 4), and two from Polesworth (Series 6). Microscopically as well as macroscopically there is a very striking similarity in all these specimens.

The quartz-grains are, as a rule, fairly well rolled, and occasionally secondary cementing-quartz occurs in optical continuity with the original grains. The true nature of the brownish felspathic grains it is almost impossible in most cases to determine, as they are much decomposed. In one or two cases, however, where decomposition has not proceeded so far, they may certainly be described as rotten glassy lavas of a rock which we may call trachyte, *i. e.* one moderately rich in silica, certainly not a basalt. Here and there a grain of felspar or of tourmaline may be detected. In one specimen, a beautifully crystalline grit, both the quartz- and lava-fragments are fringed with bristling flakes of a chlorite.

Professor Lapworth recognizes these quartzites as belonging to the lower part of the Hartshill quartzite series; but there is one important point of difference which indicates that the Permian fragments cannot have been derived from the exact locality in which the rocks are now exposed. In most of my specimens the twin lamellæ of the felspar crystals are somewhat curved, and dull shadows play over the quartz-fragments as the stage is rotated. These "strain shadows," from which the Hartshill quartzite is free, indicate that the rock must at one time have been in a state of considerable tension or compression. This is further confirmed by the fact that some of the felspathic grits show distinct signs of *cleavage*.

Gritty Slates and Flinty Slate.—I have not examined any of these microscopically, but it is clearly seen, when a very large number of specimens are examined, that they belong to the same series as the felspathic grits and quartzites, for every stage of transition can be observed. Some of the closer grained and more flinty slates resemble some of the Charnwood rocks.

Argillite.—From Series 1, I have obtained a few angular fragments of a very fine compact greenish argillite, which exhibits a curious wrinkled weathering. Under the microscope it is seen to be composed of rather uniform and fine-grained materials, which have undergone a considerable amount of micro-mineralogical change, developing ferrite and chlorite or viridite. In parts of the slide granular clusters of a light brown anisotropic mineral are developing, but generally there is a want of definite structure. Professor Bonney believes that this rock is not newer than Ordovician.

Stratified Volcanic Rock.—From each of the Series (1) and (2) I have obtained a few fragments of a rock which, macroscopically, may be described as a grit, but which, when sliced, is seen to be made up mainly of volcanic igneous rock of a distinctly basic character which has been much affected by micro-mineralogical change,

viridite, a kind of palagonite (?), &c. being produced. One of the specimens contains a few fragments of quartz, probably water-worn. The rock has, no doubt, been washed down from a basic lava. It resembles very closely some of the fragments in the coarse breccia at the base of the Hartshill quartzite, and doubtless belongs to the *Caldecote Series.*

Volcanic Ash.—The breccias of localities (1), (2), and (3) have yielded a few large and fairly well-rounded fragments of this nature, and of these I have had two prepared for the microscope. The first proves to be a rock which originally was a fine-grained volcanic ash chiefly composed of "dust," *i. e.* chips of glass, crystals, &c. rather than scoria. The lava would be a trachyte. It has been consolidated and chemically changed, the felspar crystals being replaced by secondary products, and a filmy micaceous mineral developed.

The second specimen may perhaps be described as an argillite, the materials of which are largely derived from volcanic (trachytic) dust. It has not been subsequently modified to the same extent as the rock just described. Professor Lapworth has pointed out to me that this rock resembles very closely the ashes of the Caldecote Series occurring in the Old Tunnel, and that the other specimen may also with certainty be referred to the same series.

Igneous Rocks.—Most of the fragments of igneous rock are very much decomposed, but the following are recognizable :—

Felsites.—A few fragments from localities (1), (2), and (6). These are occasionally scoriaceous and slightly porphyritic. A specimen from Packington, which is compact and minutely porphyritic, is probably an old andesite, or basic sanidine (? trachyte). From the same locality I have also obtained a quartz-felsite, which is distinctly cleaved.

In Series (5), that of the Hartshorn-Brook section, there are a large number of fragments of a rock which, from the appearance of the hand-specimens, might be described as a crushed quartz-felsite. Microscopical examination shows that the crushing has resulted in the development of a filmy micaceous mineral giving a rather brilliant colour at about 45° with the crossed nicols. There are no porphyritic felspars now recognizable. The grains of quartz appear to be of "early consolidation," and to have been slightly enlarged when the mass finally cooled. The matrix exhibits a minute devitrification-structure. The rock may be a modified fine-grained tuff, but is more likely a modified igneous rock (obsidian). Both from macroscopical and microscopical appearances Professor Bonney considers that it belongs to the Peldar-Sharpley group of rocks in Charnwood.

Besides the above we have, in No. 6, the Polesworth breccia, amongst the less decomposed fragments, several which Professor Bonney is inclined to consider *porphyritic andesites,* belonging to the *Caldecote Series.*

Diorites.—The breccias both of Packington and of Newhall Park Colliery contain more or less decomposed fragments of a rock which

is distinctly recognizable as partially decomposed *diorite*, similar to the diorites intrusive in the Upper Cambrian (Stockingford) Shales of the Nuneaton district.

Carboniferous Rocks.—Fragments referable to the Carboniferous rocks of the neighbourhood are, in the breccias of some localities, very plentiful, whilst in others they are remarkably scarce, thus forming a marked contrast to the more regular distribution of the felspathic grits which have been brought from further afield. This is well shown in the table on p. 24. As a rule, these fragments have been derived from the Coal-measures of the immediate locality, and consist of angular pieces of grit, nodules of clay-ironstone, and concretions of more or less impure hæmatite. Within the limits of the Leicestershire Coal-field fragments of Mountain Limestone are of rare occurrence in the Permian breccias. One such fragment, which was very fossiliferous, I have found at Measham, and at the Boothorpe Works (Series 1) I have found several pieces of impure limestone, resembling some of the marginal deposits of Carboniferous Limestone at the northern extremity of Charnwood Forest.

At Polesworth, at the northern extremity of the Warwickshire Coal-field, nearly 10 per cent. of the fragments contained in the breccias consist of well-rolled pebbles of compact crystalline Carboniferous Limestone *.

(4) The Origin of the Rock-fragments of the Breccias.

In attempting to trace the source from which the material now forming the Permian beds of the Ashby Coal-field has been derived, it is manifest that but little aid can be expected from the brecciated fragments derived from the Carboniferous rocks, since, as we have already observed, these grits, hæmatite-nodules, and sparsely scattered limestone-fragments have been derived for the most part from the denudation of rocks in the immediate neighbourhood, and vary much within small distances. For a solution of the problem we must question those fragments which so largely predominate in the breccias throughout the whole Coal-field, the felspathic grits and quartzites, and their associated igneous rocks.

Except in the Wrekin there are no rocks to the north and north-east nearer than Scotland which could afford specimens having the general characters of these older brecciated fragments. It is true that we occasionally find a few which can with a tolerable amount of certainty be referred to the Charnwood series; but except in one locality, that of the Hartshorn Brook, these are very rare, and form a very small percentage of the total number of fragments. If

* In the face of the above facts I think we cannot refer the source of these Polesworth limestone fragments to the bosses of Carboniferous Limestone which are exposed on the east side of the Ashby Coal-field; for were this the case we ought to find considerably more of these limestone pebbles than we do in the breccias of the country intermediate between these spots. It is far more probable that the limestone of the Polesworth breccias was derived from a mass of Carboniferous Limestone lying between the northern extremities of the Warwickshire and South-Staffordshire Coal-fields, but now covered by Triassic strata; or from a hidden boss of limestone still further to the south.

these breccias owe their present position to the action of water * only (and we have no evidence whatsoever that ice played any part in their deposition) we are precluded from looking far afield for their point of origin, since the angularity of their component fragments is too great to be consistent with a transportation by streams for more than a very few miles.

I have already drawn attention to the fact that whilst, in the northern part of the Coal-field, the breccias have a tendency to die out and to be replaced by marls, there is, on the other hand, a tendency towards greater angularity in the fragments as the beds are traced southward. These facts alone would lead us to search for the natural quarries of the breccias in a *southerly* direction, and we are thus led, both on stratigraphical and petrological grounds, to look to the Upper Cambrians of the Nuneaton and Lickey districts, with their underlying volcanic (Caldecote) series, as a probable source from which our Permians have been mainly derived.

On examining the rocks of the Nuneaton district I find that the felspathic grits, which are so predominant in the Permian breccias, can, for the most part, be identified with the Hartshill quartzite series. Some of the softer and more shaly beds of the Hartshill rock, as well as the grits at its base, are also exactly represented in the Permian breccias, but in the latter there is a more perfect gradation from quartzites into fine-grained argillaceous felspathic grits than is observable in the Nuneaton rocks. These argillaceous fragments of the breccias have, however, a close resemblance to some of the gritty shales of the Dosthill exposure of the Stockingford Shales on the western side of the North Warwickshire Coal-field.

Some of the grits of the Permian breccias are parallelled very closely, as pointed out to me by Professor Lapworth, by the felspathic grits into which the Lickey quartzite passes downwards at the south-western extremity of the Lower Lickey Range.

The Caldecote Series is represented in the breccias by fragments of volcanic ash, and, as we have seen, we are not without representatives of the *diorites* which occur in intrusive sheets in the Stockingford Shales. Of the softer portions of the Stockingford Shales we have, as might be expected, no recognizable trace; but this is not to be wondered at when we consider the ready way in which these shales disintegrate under the action of the weather †.

Although there can be little doubt about the *series* of rocks from which the Permian breccias of the Leicestershire Coal-field have been derived, there are several reasons for believing that the actual source of the fragments was not the existing outcrop in the Nun-

* Sir A. Ramsay believes that *ice* has played an important part in the accumulation of those massive beds of breccia which form such a striking feature in the Permians further south, and of which the beds we are considering are but meagre northern representatives. It has, however, been strongly maintained by Prof. Bonney that the so-called glacial striæ which have been found upon a few of the fragments are attributable to earth-movements, and have not the characteristics of true glacial markings.

† It is probable that the variegated marls of the Permian have been derived in part, at any rate, from the washing down of the Stockingford Shales.

eaton-Hartshill district. The distance from the Hartshill ridge to Packington is 12 miles, and it seems to me that the great angularity of the breccias in the last-mentioned district is incompatible with a water-transit of this extent; and I am confirmed in this opinion by Prof. Bonney, who has of late given a considerable amount of attention to questions of this nature. Independent evidence of a more positive kind that the Hartshill Nuneaton outcrop is not the exact point of derivation, is afforded by the "strain shadows" exhibited by sections of many of the grits and quartzites of the breccias. This peculiar optical property of the microscopical sections indicates a folded and disturbed state of the parent rock from which the Upper Cambrians of the Hartshill district are comparatively free.

Before we can indicate with any probability the approximate locality of the rocks from which the Permian breccias have been derived, it will be necessary to consider the position of the older Palæozoic rocks beneath the New Red Sandstones and Marls, which extend in an unbroken sheet from the Hartshill ridge to Charnwood, and to ascertain how far they were stripped of the overlying Carboniferous deposits, and subjected to denudation, in Permian times.

Over a large part of this area, as pointed out by Mr. Harrison ('Midland Naturalist,' 1885), there can be no doubt that the Trias rests directly upon rocks older than the Coal-measures, and this fact has been more recently dwelt upon by Mr. Strahan, in his paper on the "Rocks beneath the Coal-measures, and around the Warwickshire Coal-field" (Geol. Mag. 1886).

In the last-mentioned paper particulars are given of a number of deep borings through the Trias in search of coal; but by some mischance the record of one of these borings, which for my particular purpose is perhaps one of the most important, is erroneously given. The boring in question is the one referred to by Mr. Strahan (*loc. cit.*) as the *Elmesthorpe boring*, and by Mr. W. J. Harrison (Midl. Nat. viii. p. 163) as the *Sapcote boring*. Its position is at Sapcote Freeholt, halfway between Hinckley and the syenite boss of Sapcote. Mr. Strahan gives the following particulars :—

	ft.
Drift	10
Red Marl	120
Lower Keuper Sandstone [Waterstone]	330
Slaty rocks with a dip of 70°, Lower Silurian ?	1195
	1655

Mr. Harrison (*loc. cit.*) gives substantially the same account of the boring, and states his conviction that the slaty beds are Stockingford Shales.

Through the kindness of Mr. J. A. Bosworth, of Leicester, under whose superintendence the boring was made, I have been able to examine his very carefully prepared section, and also to see some of the cores. The following are the details, which, it will be seen, differ materially from those given above :—

Boring at Sapcote Freeholt.

		ft.	in.
Upper Keuper.	Alternating grey and red Marls, in part very gypseous ...	470	
	A very hard bed of conglomerate or breccia; fragments for the most part consisting of small pieces of quartz...	A few inches.	
Coal-measures.	Purple Marl	20	
	Dark-coloured shales, containing at 40 ft. from top a seam of *coal* about 4 inches thick	40	
	"Bat," *i. e.* Carbonaceous clay	0	5
	Grey and reddish sandstones, which Mr. Bosworth certainly refers to Coal-measures	150	
Upper Cambrian.	Indurated bluish (Stockingford) shales	974	
		1654	5

There are certainly no beds in the above section which can be referred to the Lower Keuper (Waterstones); the grey and red gypseous marls belong to the Upper Keuper, and have at their base a thin band of fine breccia which closely resembles a rock found in the neighbourhood of Whitwick, where the Keuper rests upon the Forest rocks. It is possible that the 20 feet of purple marls may be of Permian age, but it is more probable that they form part of the underlying shales which have been stained by percolation from above. In the 190 feet of beds below the purple marl we have unmistakable Coal-measures, containing a thin seam of coal; and these rest upon dark-coloured bluish shales, undoubtedly belonging to the Stockingford Series.

Outcrop of Stockingford Shales at Elmesthorpe.—Whilst Mr. Bosworth was executing the boring mentioned above, his attention was directed to certain indications in a railway-cutting near Elmesthorpe Station which led him to believe that the dark shales which occur below the Coal-measures in the Sapcote boring, and which we now know to be Stockingford Shales, cropped out at the surface. This observation, if correct, seemed to me of such very great importance in determining the position of the older rocks, that I took an early opportunity of visiting the place with Mr. Bosworth, and of collecting on the spot all the available evidence. The point in question is on the Leicester and Birmingham line, 1450 yards east of Elmesthorpe Station, close to the viaduct by Elmesthorpe Gorse. It is almost exactly two miles north-east of the Sapcote Freeholt bore-hole.

The railway-cutting is in chalky Boulder-clay, which is in part of a dark bluish colour, very unlike that of any other Boulder-clay in the neighbourhood. There are, at the present time, no indications of any outcrop of the shales at the base of the cutting. The matter was, however, proved beyond doubt by a trial-boring which Mr. Bosworth put down in an adjoining field on the north side of the railway. At a depth of 24 feet, after passing through dark-coloured Boulder-clay, the boring-tool struck solid blue shales, specimens of which I have seen, and which are undoubtedly identical with the Stockingford Shales of the Sapcote boring.

It is put beyond doubt therefore that between Sapcote Freeholt

and Elmesthorpe Gorse the older Palæozoic rocks rise to the north-east from under their covering of Coal-measures, and that the dip of the rocks at this point must be in the same general direction as it is in the Nuneaton district, eight miles further west *.

Market Bosworth Borings.—In the years 1880–1882 three borings were made in search of coal on the estate of Sir Beaumont Dixie, near Market Bosworth, but hitherto no information about these has been available, except the statement that in one of them Cambrian or Lower Silurian rocks were entered at 400 feet (Strahan, Geol. Mag. 1886, p. 556).

Through the courtesy of Mr. J. S. Rolleston, of Leicester, who is in possession of the cores from these borings, I have recently had an opportunity of examining them, and of obtaining information having an important bearing on the present inquiry.

The exact position of the borings is as follows :—

No. 1. At Cowpasture, ¾ mile N.E. of Market Bosworth.

No. 2. At Bosworth Wharf, ¾ mile W. of Market Bosworth.

No. 3. At Kingshill Spinney, 2 miles S.W. of the town.

(1) *The Cowpasture Boring.* — The total depth reached was 545 feet. Down to 380 feet it is in New Red Marls and Sandstones. Below this there are 53 feet of a *breccia*, consisting of very angular fragments of rock in a red marly matrix, and exactly similar in appearance to some of the Permian breccias of the Leicestershire Coal-field. *This Permian breccia rests directly on dark-coloured Stockingford Shales*, exactly similar to the shales of the Sapcote and Spinney-Hill borings. In all 112 feet of these shales were pierced when the boring was abandoned. At 500 feet a bed of igneous rock was passed through.

(2) *Boring at Bosworth Wharf.*—Total depth of boring 1364 feet. The Trias here was 744 feet thick, and at its base was a breccia 10 feet in thickness. This I should judge, from its appearance, belongs to the Trias rather than to the Permian. The breccia rests on an *igneous* rock, traversed by fine joints filled with infiltered dolomite. Below this are the Stockingford Shales, of the same type as those of the Sapcote and Spinney-Hill borings. In the upper part the beds are variegated with red, and throughout show a high angle of dip with considerable contortion and, occasionally, slickensiding. At 1251 feet from the surface a second bed of igneous rock was penetrated, 57 feet in thickness, and from this down to 1330 feet occurred bluish-black Stockingford Shales, which apparently overlie a *highly consolidated reddish breccia*, made up principally of fragments of slate and igneous rock, imbedded in a hard calca-

* It is a noteworthy fact that at Barrow Hill, only ¾ mile N.N.E. of this outcrop at Elmesthorpe, there is a small boss of igneous rock, marked on the Survey map as "greenstone." This has been described by Hill and Bonney (Quart. Journ. Geol. Soc. vol. xxxiv. 1878, p. 230) as resembling somewhat in appearance the Warwickshire diorites. It is highly probable that further investigation will prove the Barrow Hill rock to be really intrusive in the Stockingford Shales, and it is possible that some of the bosses of igneous rock of Sapcote, Croft, and Enderby may also be intrusions in the Shales or their associated rocks.

reous matrix. The boring terminated after passing through 34 feet of this rock, which resembles very much in general appearance a breccia which occurs at the base of the Hartshill quartzite, at the entrance to Boon's Quarry, near Nuneaton. There are several reasons for believing that this breccia does not naturally underlie the shales of the boring, but that it belongs to a much lower horizon than the Stockingford Shales, and owes its present position to faulting. In the first place, we may be pretty certain that the shales passed through in the boring are not the Lower Stockingford, since no black shales such as immediately overlie the breccia occur at this horizon. Secondly, as pointed out to me by Prof. Lapworth, the shales passed through just before the breccia was struck are very much "smashed" and slickensided. Then, again, it is opposed to the physics of sedimentation to find deep-water deposits, like those of the Lower Silurian Shales, abruptly succeeding breccias without any signs of a passage. Taking all these facts into consideration, I think there can be no doubt that the Bosworth Wharf boring, at a depth of 1330 feet, passed through a *fault* which throws up the basement-beds of the Hartshill quartzite on the east in contact with the middle portion of the Stockingford Shales on the west.

(3) *Boring at Kingshill Spinney.*—This boring was carried to a total depth of 1030 feet, and appears to have been in the Trias throughout. The lower part is in a coarse sandstone containing rounded pebbles, evidently the Bunter Conglomerates, which are more fully developed six miles further west, near Polesworth, and again eight miles N.N.W., on the margin of the Ashby Coal-field. Taken in conjunction with the other borings of the neighbourhood, the results are of interest as fixing the easterly limit of the Bunter in this part of the country.

These three borings at Market Bosworth are situated approximately along a line running N.E. and S.W., and they prove beyond doubt the important fact that, in this neighbourhood, just as further south, near Elmesthorpe, the older Palæozoic rocks underlying the Trias rise rapidly towards the north-east, and that a line joining Market Bosworth and Sapcote Freeholt must mark the *axis of a sub-Triassic anticlinal ridge of the older rocks.*

Now the direction of this line is about N.N.W. and S.S.E., and it is, consequently, *parallel with the Nuneaton-Hartshill and Charnwood axes of elevation, and also with the general direction of the major folds and faults of the Leicestershire Coal-field further north.* On the western side of this ridge the general dip and relative position of the Upper Cambrian and the Coal-measures, when these latter are present, must be the same as in the neighbourhood of Nuneaton. We have shown reason for believing that this is a faulted anticlinal with a downthrow to the west; and if we could sweep away the covering of Triassic sediment we should doubtless find the Hartshill quartzites and the equivalents of the Caldecote Series rising from under the Stockingford shales a little to the north-east of Market Bosworth. Since we know with certainty that the Carboniferous strata were denuded from the older rocks in Permian times (for at

the Cowpasture boring the Permian breccias rest directly on the Stockingford Shales), *we have, in the northern part of this ridge of old rocks a very probable source of the angular fragments occurring in the Permian beds five or six miles to the north-west.*

There is another fact in favour of this view which we must not lose sight of. The Stockingford Shales pierced at Market Bosworth, unlike the beds of the same age near Nuneaton, are much contorted and slickensided, and even show signs of cleavage. We have seen that there are microscopical indications of the fragments from the Permian breccias having been subjected to considerable pressure and strain, such as might be expected from rocks exhibiting the above general appearances. The horizontal section (fig. 6) shows, in a diagrammatic form, the probable position of the older rocks beneath the Trias along a line drawn from Nuneaton to Charnwood Forest.

In addition to the hidden anticlinal of the older Palæozoics just referred to, the shaft of the Lindridge Colliery, about half a mile north of Desford, has afforded evidence of still another fold between the Market Bosworth axis and Charnwood *; so that, taking all the facts into consideration, we have ample proof that the dominant N.N.W. and S.S.E. folding of the older rocks is continued between Nuneaton and Charnwood, underneath the Triassic plain, which is bounded by the Ashby Coal-field on the north, the Warwickshire Coal-field on the west, the Liassic escarpment on the south, and by Charnwood Forest on the east.

So exact is the parallelism of the major foldings and the principal system of faultings in the Leicestershire Coal-field with the folding in what we may term the Nuneaton-Charnwood area, that it is impossible to doubt that the general trend of the rocks in the two contiguous areas has been brought about by the same series of earth-movements.

That the age of these movements † is, in the main, Post-Carboniferous is beyond doubt, for we find both the older Palæozoics and the Carboniferous rocks equally affected by them; but whilst in the Nuneaton-Charnwood area we have nothing, so far as I know, which fixes more definitely the age of these flexures, we have, on the other hand, a valuable chronological index in the thin Permian beds of the Leicestershire Coal-field; for the non-participation of these strata in the general folding of the older rocks, and the undisturbed way in which they lie, bridging over the great N.N.W. and S.S.E. faults, proves the age of the disturbances to be Pre-Permian.

* Mr. Bosworth informs me that two borings and a shaft have been sunk at Lindridge. In the first boring, after passing through from 370 to 380 feet of hard brown and red Keuper sandstone, a rock was reached which is described as *syenite*. In the second boring, about half a mile further west, Coal-measures were struck and coal actually found. The *shaft* was ultimately sunk three quarters of a mile east of the second boring, and, by a curious chance, came down exactly upon a very sharply *faulted anticlinal*, with Coal-measures dipping away to the west and syenite to the east.

† The forces which brought about the cleavage of the Charnwood rocks, although acting along nearly the same lines as the Post-Carboniferous disturbances, must be of vastly earlier date.

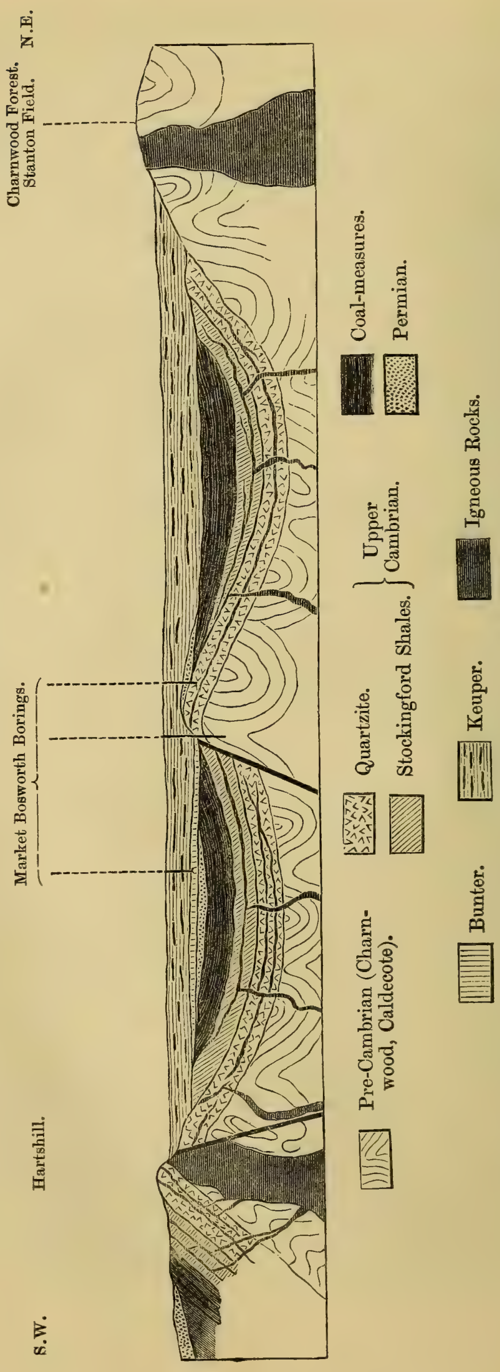


Fig. 6.—*Diagrammatic Section from Hartshill to Charnwood Forest, showing the Sub-Triassic Ridge of Older Rocks near Market Bosworth.*

The influence of these Pre-Permian movements is observable from the South-Staffordshire Coal-field to Charnwood Forest; and, through the Leicestershire Coal-field and the exposure of Lower Carboniferous rocks at Kirk Langley, the disturbance can be connected with the great Pennine axis, to the southerly extension of which they doubtless owe their origin; consequently the Permian beds we are considering afford indirect proof of the correctness of the view of Mr. E. Wilson and Mr. J. J. H. Teall as to the Pre-Permian age of the Pennine axis.

(5) Correlation of the Beds, and a Consideration of the Physical Conditions under which they were deposited.

On the extreme north of the Warwickshire Coal-field, about six miles S.S.W. of the most southerly exposures of the Permians of the Leicestershire Coal-field, there occurs, near Polesworth, an outcrop of Permian rocks, consisting of consolidated calcareous breccia and buff-coloured sandstone, the latter underlying the former. The breccia, to which reference has been already made, immediately underlies the Bunter Conglomerate, and is apparently from 200 to 300 ft. thick. From its general appearance, and from the nature of its included fragments (see p. 24), there can be no doubt that it is identical with the brecciated rocks overlying the Coal-measures of the Leicestershire Coal-field to the north; and as the buff-coloured sandstones are exactly similar to the characteristic Permian sandstones which I have described as occurring at Swadlincote and Caulkley Wood, the Polesworth rocks are doubtless southern extensions, in a more massive form, of the Permians which occur in the Leicestershire Coal-field as comparatively thin, marginal deposits. On the other hand, the Permians of Warwickshire can be directly correlated with those of South Staffordshire by the aid of various exposures between the northern extremities of the South-Staffordshire and Warwickshire Coal-fields; so that we are justified in regarding the Permian rocks of these districts, and of the Leicestershire Coal-field, as belonging to the same area of deposition, and as forming a part of the detrital deposits of the great Permian lake, which extended northwards from Warwickshire and Worcestershire, and the margin of which was the Pennine Chain.

There is, however, one important fact which remains to be noticed. In the Warwickshire district (and I believe also in that of South Staffordshire) the break between the Coal-measures and Permian is very much less than it is in the Leicestershire Coal-field; in fact, according to most observers, there is, in the former district, almost an unbroken stratigraphical succession from the Upper Coal-measures, with their *Spirorbis*-Limestone, into the Permian. This striking difference in unconformity in areas so near to each other can, I think, be explained by the fact that the Leicestershire Coal-field, where the greatest stratigraphical break takes place, is almost directly on the line of the Pennine-Charnwood axis, along which the

effects of the great Post-Carboniferous, Pre-Permian movements were at a maximum.

Our Leicestershire rocks, on the other hand, are so entirely dissimilar, both in lithological characters and succession, to the deposits which occur on the eastern side of the Pennine chain from Nottinghamshire to Durham, and which doubtless underlie a large portion of the north-east of England, that on this account alone we should suspect that the two series were laid down in different basins. We have seen that the Leicestershire rocks thin out rapidly to the north-east and east against an old land-barrier; and Mr. E. Wilson, F.G.S. ('Midland Naturalist,' vol. iv. p. 97 *et seq.*), has clearly shown that, whilst the Permians of the north-east of England thicken out towards the north and east, and acquire in these directions the characters of deeper-water deposits, the same beds when traced to the southward become more arenaceous, thin out, and ultimately die away altogether in the neighbourhood of Nottingham, owing to the Coal-measures rising up beneath them and forming what, in Permian times, was a land-barrier.

The most northerly exposure of the Leicestershire Permian is at Ingleby, 13 miles south-west of the nearest outcrop of the Nottinghamshire Permian. North and east of Ingleby the Permian is absent *, and we know, from the results of trials for coal at Wilford, Clifton, Highfield, Chitwell, and Owthorpe, that the same is the case to the south and south-west of Nottingham. These facts prove the existence of a land-barrier between the two Permian lakes at this point; and there can be but little doubt that this had its origin in the southerly extension of the Pennine disturbance, which we have seen produced well-marked effects even much further to the south.

It is possible, after making due allowance for a certain amount of denudation in Bunter and Lower Keuper times, to trace, with a fair approximation to accuracy, a small portion of the old coast-line of the western Permian lake. Its probable course, commencing on the north, was through Stanton-Bridge, Ticknall, Hartshorn, Blackfordby, Ashby, a little west of Heather, Market Bosworth, then on towards the northern part of the Warwickshire Coal-field, whence it must have taken a southerly course for some distance, thus forming a somewhat deeply indented bay facing north-west. The rocks forming the land on the south of this bay had already been folded in a north-north-westerly and south-south-easterly direction; and since this folding of the Carboniferous and older Palæozoics brought to the surface beds of varying hardness, there must have resulted a series of ridges and valleys to some extent coincident with the strike of the beds, and resembling very much the contour of the ground at the present time in the Nuneaton-Hartshill district. Down these strike-valleys flowed the streams, bringing detritus into the Permian lake from the high ground on the south. We have

* The so-called Permian between Derby and Ilkeston has been shown by Mr. Wilson to be brecciated Bunter sandstone, and that of Dale Mill to be Lower Coal-measure sandstone.

proof that denudation had bared some of the older rocks of their overlying Coal-measures, and it is the re-arranged *talus* and "*screes*" from the harder portions of these older rocks which now form the brecciated bands in the Leicestershire Permians *.

(6) APPENDIX.

The Igneous Rocks of the Market Bosworth Borings.

The igneous rocks which have been penetrated in the deep borings of Bosworth Wharf and the Cowpasture, near Market Bosworth, have not hitherto been described. They occur, as we have already seen, at the northern end of the Sub-Triassic ridge, which extends from Sapcote to Market Bosworth, and they appear to be intrusive in bluish-black shales, which, we have every reason to believe, are identical with the Stockingford Shales of the Nuneaton district. The fact that fragments of these igneous rocks, doubtless derived from this immediate neighbourhood, occur in the Permian breccia a few miles further north, is sufficient excuse for my dwelling somewhat in detail upon the results of their examination.

I must once more express my thanks to Professor Bonney for his careful examination of the slices of these rocks, and to Mr. T. H. Waller for a determination of their relation to the Warwickshire diorites, with which he is so well acquainted.

1. *From the Cowpasture Boring.* Depth 509 feet.—This is a moderately fine-grained rock, which was probably once an ophitic dolerite. The felspar is plagioclase, but much altered, and the pyroxenic mineral has been replaced by pale viridite, with a few specks of opacite. There are some crystals and grains of iron-oxide, which are doubtless in part hæmatite, and some pyrite. There is a little free quartz, which, from its frequent association with calcite or dolomite, may be looked upon as probably of secondary origin.

2. *Bosworth Wharf Boring.* Depth 1275 feet.—The minerals of this specimen are much decomposed. It is a holocrystalline mixture, chiefly of felspar and pyroxene mineral, the former being of a grey brownish colour in transmitted light, but with crossed Nicols giving very pale whitish-grey tints, and still distinctly indicating the twinning of *plagioclase*, probably labradorite.

The pyroxene mineral is replaced by a very pale-green mineral, which, with crossed Nicols, shows an aggregate structure acting very feebly on polarized light, and a brown or black ferruginous mineral. The latter is often arranged in parallel flakes, indicating that its deposition has been determined by pre-existing cleavage-planes. The pyroxene constituent has consolidated later than the felspar, so that the rock has an ophitic structure.

There are some hexagonal prisms of apatite and a little dolomite (?).

3. *Bosworth Wharf Boring.* Depth 1265 feet.—This is an ophitic

* An excellent example of such a rearranged *talus* from the Charnwood rocks may be seen in the thick Keuper breccia on the flanks of Charnwood Forest at Thringstone.

diorite (?), differing only varietally from No. 2. There appear, however, in this case to have been two varieties of pyroxene, but there is not much of the pale-green "viridite," the iron-stained constituents predominating. The possibility of the latter having been hornblende is suggested by the appearance of one or two grains.

4. *Bosworth Wharf Boring.* Depth 774 feet.—The core from which this slice has been cut exhibits two distinct colours of rock, the one being of brownish red and the other of a greenish tint. The line of separation between the two is a crack, which has been filled with crystalline dolomite.

Microscopically, the rock resembles Nos. 2 and 3, but is less coarsely crystalline. Some of the pyroxenic constituents suggest the former presence of hornblende. The brown and greenish rocks have the same general appearance.

These rocks are all in a very decomposed condition. Professor Bonney informs me that they certainly do not appear to belong to the Charnwood or Narborough type, nor even to Barrow Hill, but that apparently they have some relation to the Warwickshire diorites. It is difficult to decide, however, whether the Bosworth rock is a *diabase* or a *labrador-diorite*; but, on the whole, there is a probability that the principal pyroxene constituent was a hornblende.

Mr. T. H. Waller, after a careful comparison of these slices with his extensive collection of the Warwickshire diorites, informs me that the Market Bosworth specimens appear to be very similar to the diorites which occur in sheets in the Hartshill rocks of the Nuneaton district, but that from their decomposed state it is impossible to speak with absolute certainty on this point.

EXPLANATION OF PLATE I.

This Plate represents the section in the open-work at Swadlincote as it appeared in March 1888. The Bunter Conglomerate and Lower Keuper Sandstone and Marls rest, almost horizontally, upon highly inclined Permian rocks, which are in turn unconformably underlain by Coal-measure Clays containing Coal-seams.

DISCUSSION.

The PRESIDENT referred to the derivation of the materials of the Permian breccia as an important instance of results due to investigation by local students, and the light thereby thrown on ancient physiography. He was sceptical as to the lacustrine origin of these breccias. Why not subaerial, like those in the interior of Asia?—subangular masses, transported by rainwash to a distance of 10 or 12 miles. He spoke of the value of the hand-borer, and referred to the specimens exhibited at the Geological congress.

Prof. BONNEY had accompanied the Author occasionally, and spoke of the paper as the cream of a series of observations, such as could only be carried out by one living in the district. It was full of interesting considerations. He agreed as to the existence of a barrier of land linking the old area of Warwickshire with Charn-

wood, and that the breccias did not obtain materials from the Lickey, the east side of which he believed to have been partly covered by Coal-measures at that period. The specimens were not exactly of the Hartshill type, and he was prepared to believe that they came from a ridge now no longer visible. He thought, from the nature of the cleavages in the older rocks of Charnwood, that there must have been pre-Carboniferous movements also in that district. He commented on the small volume of these Permian breccias. They differ in this respect and in the general character of their materials from those of the Bunter, the origin of which he believed to have been quite different. The latter, he thought, as he had often stated, had come from the north.

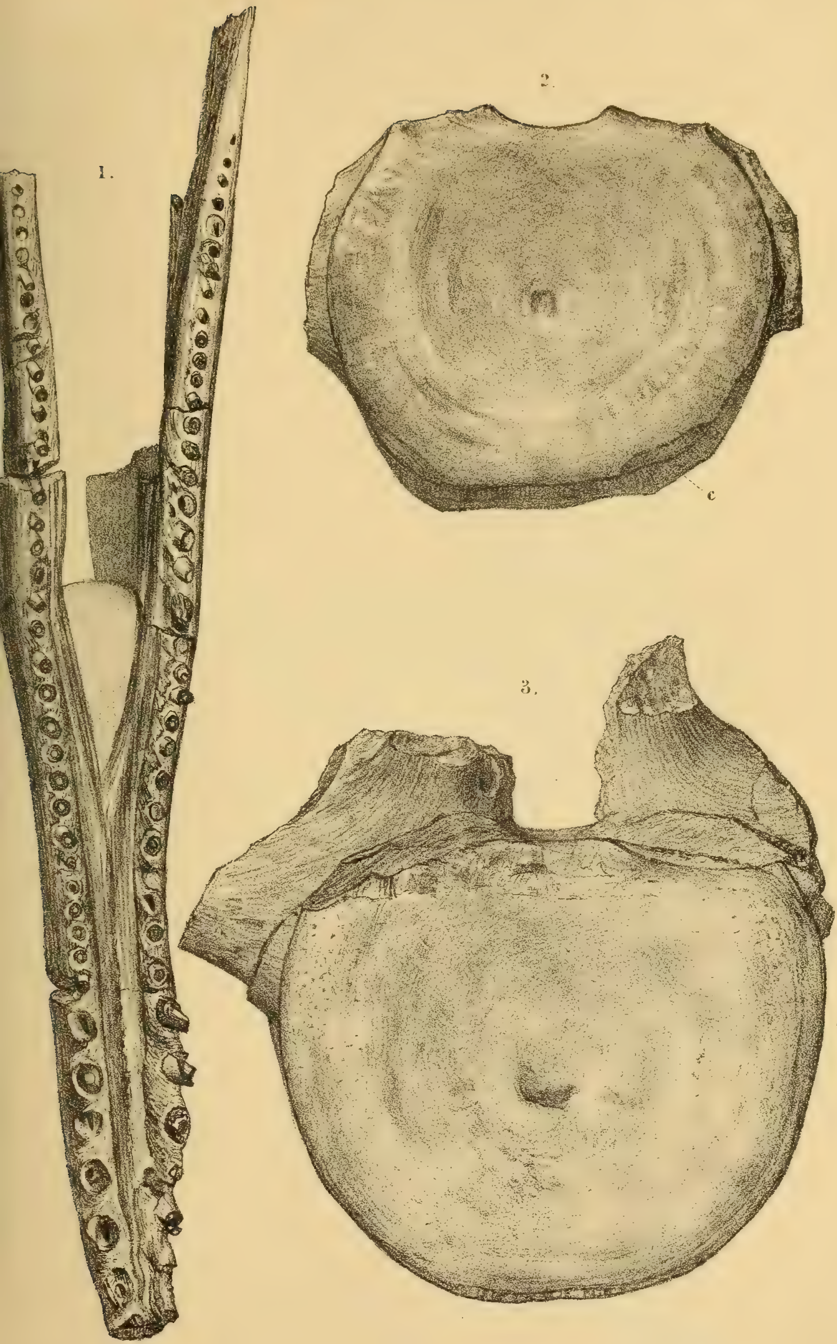
Mr. Whitaker spoke of the advantages of the 6-in. ordnance-maps. He agreed with Prof. Bonney that only those who resided in a district could do some kinds of detailed work. The materials of pebble-beds are usually of the least destructible materials. It was unreasonable to suppose that conglomerates should always have been derived from exposures now visible. Therefore the alleged underground extensions may easily have furnished these materials. Were the Charnwood rocks of fairly indestructible material? It was difficult in some cases to say to what series isolated patches of sandstones belonged: he was happy to find that the Survey had been sometimes right. He would be glad if good lithological differences could be recognized.

Prof. Blake could appreciate the value of the work, and agreed as to the relations between these beds and the Carboniferous. Was the Permian age so very distinct from that of the Trias? Mr. Wilson regarded the Permian and Trias as really one physical sequence. Are they, then, really separated by such a wide gap? He commented on the appearances at the Swadlincote section. Why might not these Permian beds represent the base of a new epoch? The stones in the deposits on the eastern side were quite different. When the Trias escapes from the Permian it becomes irregular. Were the Coal-basins separated by the Permian movements? If so, the materials dispersed should form the base of the Permian. Is there evidence that these beds belong to a distinct epoch from the Trias and are not merely its base?

Mr. Topley observed that the main point of the paper was the relation of the beds called Permian to those above and below. The Author had well traced out the underground ridge, but what is the evidence of its being a faulted anticlinal? He referred to the use of the hand-borer, and stated that it had been much used by the Geological Survey during the last two years, especially in the Isle of Wight, where Mr. C. Reid had made over 300 trial borings. The hand-borer had been long employed by the Geological Survey of Belgium, and that used by the English Survey was supplied by M. Dupont on the Belgian pattern.

The Author, in reply, stated that he was not prepared to uphold the lacustrine origin of the breccia; but if subaerial it would make no difference to his argument. With regard to the age of the Charnwood

anticlinal, the Post-carboniferous movements took place along old lines of disturbance. The scarcity of Charnwood rocks he thought due to the drift having been from the south, and this would help to account for their exceptional abundance at Hartshorn. He had orignally been prejudiced in favour of the Permian being the base of the Trias, but found the theory untenable. The material was different from that of the Eastern Permian and from the material which makes up the basement breccia of the Keuper at Castle Donington. The maximum angularity of the breccia in the southern part of the area was another point in favour of its derivation from a southern source. As regards evidence of a faulted anticlinal in the subtriassic ridge, the shales were found to be in a smashed condition, and instead of coming to quartzites below, something altogether different was found—appearances which could only be explained on the supposition of faulting.



H. Michael del. et lith.

Mintern Bros. imp.

PELONEUSTES PHILARCHUS.

2. *On the* Remains *and* Affinities *of five* Genera *of* Mesozoic Reptiles. By R. Lydekker, Esq., B.A., F.G.S. (Read November 21, 1888.)

[Plate II.]

Introductory.

The following communication treats of certain remains referred to four species of English Mesozoic Reptiles, some of which were first described or named by Professor H. G. Seeley, and also includes a discussion as to the affinities of a fifth form. The substance of that portion of the paper relating to *Peloneustes philarchus* was previously brought under the notice of the Society at the Meeting held on May 23rd as a separate communication, entitled "On the Skeleton of a Sauropterygian from the Oxford Clay near Bedford" *, but, on account of a change of view on the part of the Author, it was considered advisable that it should be again presented in a revised form.

I. Vertebræ of an Ornithopodous Dinosaur from the Cambridge Greensand.

On page 621 of a memoir on the remains of Dinosaurs from the Cambridge Greensand, published in the 35th volume of the Society's 'Journal,' Professor Seeley applied the name *Syngonosaurus macrocercus* to a series of nineteen vertebræ from the cervical, dorsal, sacral, and caudal regions, which were said to be associated, and indicate a medium-sized species. At the conclusion of the description of these vertebræ mention is also made of certain dermal scutes, which it was suggested might also be associated. I have no intention of entering into the question whether the alleged association of all these remains is absolutely certain, and I shall accordingly confine my remarks to the one cervical and eight dorsal vertebræ, which, as being the first described (although not figured), may, I presume, be regarded as the types.

All the dorsals are amphicœlous, and characterized by their compressed centra to which the arches are firmly united, the absence of rib-facets on the arches, and the height of the neural canal. In the four anterior dorsals the centrum is comparatively short, with triangular terminal faces and a sharp hæmal ridge; while in the four later ones the centrum is longer, the hæmal ridge disappears more or less completely, being represented by a tubercle at either end †, and the terminal faces are less triangular. In the anterior dorsals the length of the centrum varies from 1·5 to 1·7 inch; while in the first of the four later ones this length is 1·75, and the height from the base of the centrum to the summit of the neural platform 2·5 inches.

Prof. Seeley makes no attempt to determine the serial position of

* Proc. Geol. Soc. 1888, p. 89.

† I take the character from page 621 of Prof. Seeley's memoir; there is some discrepancy with this on p. 623.

Syngonosaurus, although he suggests affinity to another Cambridge form described in the same paper under the name of *Eucercosaurus*. The caudals of the latter are, however, stated to show some resemblance to those of *Hylæosaurus*, but the dorsals are compared with those of the Iguanodonts. In the absence of figures it seems difficult to see how the dorsals described as *Eucercosaurus* differ from those of *Syngonosaurus*.

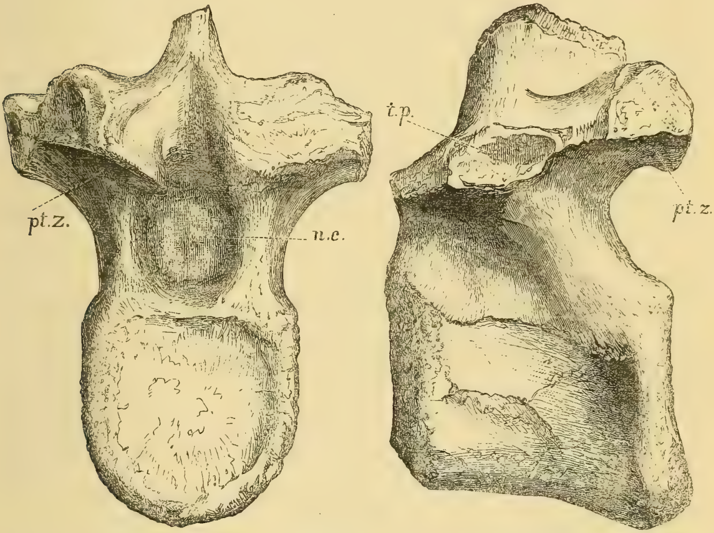
In recently looking through a number of undetermined specimens from the Cambridge Greensand in the British Museum, I noticed four imperfect dorsal vertebræ (No. R. 460) of a comparatively small Dinosaur, all of which were obtained at the same time and are probably associated. One of these vertebræ has been fractured transversely, and on polishing the broken surfaces of the centrum there appeared to be a median cavity suggesting Theropodous affinities; on cutting longitudinally a second centrum it appeared, however, that the supposed cavity was merely due to decay, and that the centrum consisted internally of the coarse cancellous structure found in the Ornithopoda (in which group I include the Stegosauria of Professor Marsh).

The two best-preserved specimens respectively correspond so closely with Prof. Seeley's description of the anterior and later dorsals of *Syngonosaurus*, that I should have had no hesitation in referring them to that form, were it not for the difficulty I find in distinguishing the dorsals of the latter from those described as *Eucercosaurus*. I will, however, provisionally regard them as referable to the former genus, and I bring them to the notice of the Society because they appear to me to afford fairly sufficient evidence as to the approximate serial position of that genus. The anterior dorsal has the triangular terminal faces and strongly marked hæmal ridge characteristic of the type specimens; the length of the centrum being 1·45 inch, and its width superiorly 1·3 inch. The arch is too much damaged for description.

In the later and probably middle dorsal (fig. 1) the greater part of the arch is preserved, but the centrum is somewhat damaged anteriorly, and has been restored in the figure from another specimen. The length of the centrum is approximately 1·6 inch, and the height to the summit of the neural platform 2·5 inches. The lateral surfaces of the centrum are flattened and somewhat depressed, the terminal faces have an approximation to a triangular contour, the neural arch is tall, and the hæmal ridge absent. The most important features of the vertebra are, however, to be found in the neural arch. The base of the broken transverse process is clearly shown, but neither in front of this, nor below it on the anterior border of the arch, is there any trace of a rib-facet, thus clearly showing that the head of the rib articulated with a "step" on the transverse process, as in Crocodiles. This negative feature being also shown in the anterior dorsal, and in all of the type specimens, is evidently constant throughout the dorsal series. Another marked feature is the absence of a deep fossa immediately in advance of the postzygapophysis.

Now these two negative features at once distinguish this type of dorsal vertebra from all genera of Iguanodontidæ and Trachodontidæ in which the vertebræ have been described *; the whole of the series of anterior and middle dorsals in these families having a distinct rib-facet on the arch, either immediately in advance of or somewhat below the transverse process, and a deep fossa between the latter and the postzygapophyses †. In the Sceli-

Fig. 1.



(?) *Syngonosaurus macrocercus.*—Posterior and left lateral aspect of a dorsal vertebra, from the Cambridge Greensand; nat. size. *t.p.*, transverse process; *pt.z.*, postzygapophysis; *n.c.*, neural canal.

dosauridæ, however, the dorsal vertebræ of the type skeleton of *Hylæosaurus*, although of considerably larger size, agree with the present specimens in the above-mentioned characters, and show most distinctly the "step" on the transverse process for the articulation of the head of the rib. If, indeed, the two specimens under consideration be compared with the eight dorsals still remaining in apposition in the type skeleton of *Hylæosaurus*, an extremely close resemblance is noticeable. Thus the shorter and carinated vertebra resembles in contour the penultimate vertebra of that series, while the figured specimen agrees equally closely with the last and latest of the series in question, and also with a detached middle dorsal seen on the right of the slab.

* With the possible exception of those figured by Prof. Cope (Rep. U. S. Geol. Surv. Terr. vol. ii. pl. i.) as *Cionodon*.

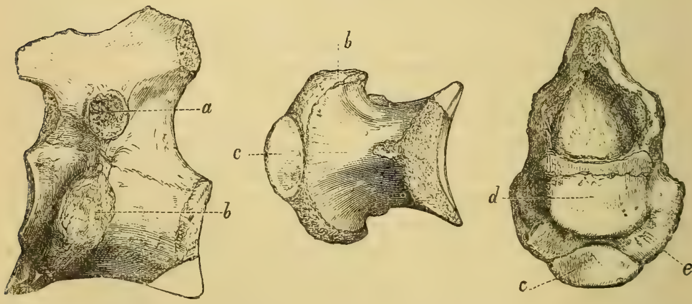
† Compare the figure of the dorsal of *Iguanodon* on p. 47 of the preceding volume of this Journal.

I think, therefore, that I have now adduced sufficient evidence to show that the vertebræ under consideration, which present no characters by which they can be distinguished from the dorsals of *Syngonosaurus*, indicate a Dinosaur apparently allied to *Hylæosaurus*. They resemble also to a great extent the dorsal vertebræ from the Wealden figured in pl. xxi. of the 35th volume of this Journal, under the name of *Vectisaurus*; which genus I have suggested, in my paper on Dinosauria in the preceding volume, may also be a member of the Scelidosauridæ. This reference is confirmed by a closer study of fig. 4 of that plate, where the capitular articulation of the rib is seen to form a distinct "step" on the transverse process, after the fashion of *Hylæosaurus*. Finally, if I am right in the position I would assign to these forms, there would be considerable probability that the dermal scutes provisionally referred to the type skeleton of *Syngonosaurus* are rightly associated either with that or one of the allied forms. And I may add that, with the present insufficient evidence, I have purposely refrained from discussing whether all or any of the above-mentioned forms are really entitled to separation from genera of earlier date.

II. Axis of a (? Theropodous) Dinosaur from the Wealden.

In looking through some undetermined specimens among the Fox Collection from the Wealden of the Isle of Wight, now in the British Museum, I was struck with certain peculiarities exhibited by an axis-vertebra (No. R. 1412), which forms the subject of this notice. The specimen (fig. 2) is incomplete, having lost the neural

Fig. 2.



Left lateral, hæmal, and anterior aspects of the axis-vertebra of a Dinosaur from the Wealden of the Isle of Wight: ½ nat. size. *a*, upper (diapophysis), *b*, lower (parapophysis) costal articulation; *c*, axial intercentrum (hypapophysis); *d*, articulation for centrum of atlas (odontoid process); *e*, articulation for the inferior ring (intercentrum) of the atlas.

spine, the zygapophyses, and part of the posterior articular face. The centrum is opisthocœlous, and shows the characteristic early Croco-

dilian and Dinosaurian feature of carrying the upper costal articulation on the arch, and the lower on the centrum. Its Dinosaurian nature is proved by the opisthocœlous centrum; and I shall show below that there is a considerable probability that it belonged to the Theropodous group of that order.

The most peculiar feature of this specimen consists in the presence of a distinct intercentrum (hypapophysis) on its anterior border, which I have not seen described in any member of the order. The flattened kidney-shaped surface, marked *d* in the figure, is evidently for the articulation of the odontoid process, or centrum of the atlas; while the marginal receding surfaces (*e*) are for the inferior ring of the atlas, which is now generally regarded as representing the first intercentrum *, or that between the cranium and the atlas.

Compared with the very small figure of the axis of *Ceratosaurus* given by Prof. Marsh in the 'Amer. Journ.' ser. 3, vol. xxvii. pl. x. (1884), the general resemblance is so close as to indicate the strong probability that the present specimen belongs to the same suborder; and it therefore seems highly likely that it may be referable to the Wealden species of *Megalosaurus*, or to a nearly allied form. In the American genus, however, the centrum of the atlas is anchylosed to that of the axis to form an odontoid process; and from the forward projection of the inferior border of the anterior part of the centrum of the axis it would appear that the second intercentrum, or that between the atlas and axis, is likewise anchylosed to the centrum of the latter. This appears to be the view adopted by Dr. Baur, who, on page 289 of the memoir cited, observes that in Crocodiles "the hypapophysis (intercentrum) between the axis and atlas is probably coössified with the anterior and lower part of the axis-centrum, as in Birds and some Dinosaurs."

The present instance of the persistence of this second intercentrum as a separate ossification in a Wealden Dinosaur is a circumstance of considerable interest, apparently pointing to the derivation of the order from Reptiles in which this was always the case. Whether any of the earlier Crocodiles exhibit a similar feature will be a matter for future investigation.

III. Femur of an Iguanodont Dinosaur from the Oxford Clay near Peterborough.

The only evidence hitherto recorded of the existence of Iguanodont Dinosaurs in England during the period of the Oxford Clay is based upon a right femur described and figured by Prof. Seeley in vol. xxxi. p. 149, pl. vi. of the Society's 'Journal' for 1875, under the name of *Cryptosaurus eumerus*. That specimen, of which the precise locality seems to be unknown, is preserved in the Woodwardian Museum at Cambridge, and indicates a comparatively small species, its total length being 12·25 inches. The grounds on which that specimen was made the type of a distinct genus are stated to be

* See Baur, Amer. Nat. vol. xx. pp. 288–293 (1886).

the extreme stoutness of the shaft and the total absence of a distinct distal intercondylar groove on the anterior aspect. The name *Cryptosaurus* is, however, preoccupied by Geoffroy, and this form, assuming it to be distinct from other types, accordingly requires a new generic name, for which I would propose *Cryptodraco.*

During a visit to the collection of Reptilian remains from the Oxford Clay near Peterborough in the collection of Mr. A. N. Leeds, of Eyebury, I was shown the left femur of an Iguanodont Dinosaur, which I thought might perhaps prove identical with *Cryptodraco.* This specimen the owner has kindly permitted me to bring to the notice of the Society. The middle portion of the shaft has been considerably crushed and broken, but both extremities are entire. The shaft agrees with that of the femur of *Hysilophodon* and of the North-American *Camptosaurus* (*Camptonotus*), and differs from that of *Iguanodon* in its markedly forward arcuation. The inner trochanter has lost its free extremity, but the basal portion shows that it is of the "pendant" type characteristic of the two former genera, and not of the "crested" type found in *Iguanodon**. The anterior intercondylar groove is slightly less developed in this specimen than in either of the Wealden genera, but it is still present. Compared with the type of *Cryptodraco* this bone differs very widely, so that there can be no doubt as to both its specific and generic distinctness. Thus it is much more slender; its shaft more curved; the head smaller instead of larger than the great trochanter; the lesser trochanter thinner and taller; and the distal end less flattened, and with a distinct intercondylar groove. The inner trochanter is wanting in the larger bone.

Leaving, then, the femur of *Cryptodraco* on one side, as indicating a totally distinct form, we may look around for other described Iguanodonts with which to compare our specimen.

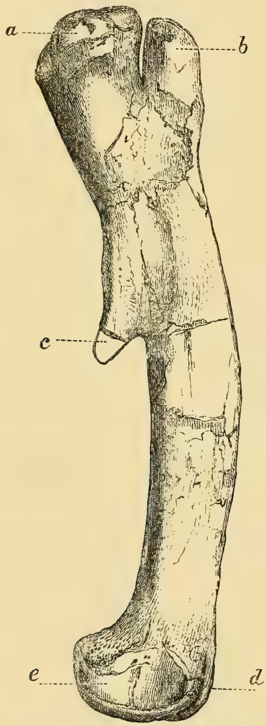
The close relationship existing between the Reptiles of the Oxford and Kimeridge Clays (those of the former being frequently somewhat smaller than their allies of the latter) suggests that the present form may be closely allied to *Iguanodon Prestwichii* of the Kimeridgian, which was described some years ago by Mr. Hulke in our 'Journal,' and which Professor Seeley last year proposed to separate generically under the name of *Cumnoria.* The entire femur of that form is unfortunately unknown, but it could evidently have been only slightly larger than the present specimen, with which (as I have satisfied myself by personal examination) the terminal extremities agree very closely. Evidence of affinity between that species and *Camptosaurus* is shown by the angulated and flattened hæmal surface of the sacral vertebræ, and by the absence of anchylosis between these centra. Having, therefore, two Iguanodonts from contiguous deposits, both of which show marked signs of affinity with *Camptosaurus*, the presumption becomes very strong indeed that they are closely allied. There is, indeed, no decisive

* Attention is directed to these two types by M. L. Dollo in an interesting article published in the 'Bull. Sci. France et Belgique,' 1888, pp. 215–224.

evidence to prove that the present specimen indicates a form specifically distinct from the species from the Kimeridge Clay; but since most of the Sauropterygians of the Kimeridge are distinct from those of the Oxford Clay, I think it highly probable that the same may hold good with the Dinosaurs, and I therefore propose to provisionally regard the present specimen as the representative of a distinct species which may have been somewhat smaller than *Iguanodon Prestwichii*.

With regard to the generic name, I may observe that, in a paper communicated last year to the Society's 'Journal,' it was stated that I

Fig. 3.



Inner aspect of the left femur of *Camptosaurus Leedsi*; from the Oxford Clay near Peterborough. $\frac{1}{3}$ nat. size. *a*, head; *b*, lesser trochanter; *c*, inner trochanter; *d*, intercondylar groove; *e*, inner condyle.

was not then satisfied as to the necessity of separating *I. Prestwichii* from *Iguanodon*. The features shown by the present femur (assuming that I am right in regarding it as indicating a form allied to that species) totally alter the case; and since I can see no characters by which either this specimen or *I. Prestwichii* can be separated from *Camptosaurus*, I propose to refer both the Kimeridgian and Oxfordian

species to that genus under the respective names of *C. Prestwichi* and *C. Leedsi*, and thus relegate *Cumnoria* to the rank of a synonym, till it can be shown to have well-marked distinctive features.

So far nothing has been said as to how the present specimen can be distinguished generically from the femur of *Hypsilophodon*; I find, however, that its inner trochanter is rather more wing-like in shape than in that genus. In a recent number of the 'Geological Magazine'* I have called attention to an imperfect femur in the British Museum (No. R. 167)† from the Wealden of the Isle of Wight, which has been referred to *Hypsilophodon*, and have suggested that, together with a mandibular ramus (No. R. 180)‡ from the Wealden, hitherto regarded as that of a young *Iguanodon*, it probably indicates a form allied to *Camptosaurus*. A comparison of this femur with the subject of the present communication shows such a close similarity between the two that there is every probability of their generic identity; and since there is no other evidence of the existence of a *Hypsilophodon* of these dimensions, I propose to apply the name *Camptosaurus valdensis* to the Wealden form, of which I take the femur as the type, and provisionally associate with it the mandibular ramus.

I may add that the ilium of the type species of *Camptosaurus* is remarkable for the extreme shortness of its preacetabular process. We have no evidence of the contour of this portion in *C. Prestwichi*; but even if there should be a difference in this respect I should not be disposed to regard it as of more than specific value. Finally, I see no reason to remove *Iguanodon Dawsoni*, of which I published the description in the above-mentioned paper, from the type genus.

IV. On the Skeleton of a Sauropterygian from the Oxford Clay near Bedford.

On page 139 of his 'Index to the Fossil Remains of Aves, Ornithosauria, and Reptilia in the Woodwardian Museum at Cambridge,' published in 1869, Professor Seeley applied the name *Plesiosaurus philarchus* to the greater part of the skeleton of a Sauropterygian from the Oxford Clay of Peterborough, which was collected by Dr. H. Porter, and is preserved in that Museum. The type specimen comprises part of the cranial rostrum, the nearly entire mandible, with the teeth broken off, the vertebral column, and the pectoral and pelvic limbs, with portions of their respective girdles.

Unfortunately, none of these remains have ever been figured, and it appears to me somewhat doubtful whether the description is sufficient for the definition of a species. Since, however, by inspection of the specimen itself, I have been enabled to satisfy myself of its specific identity with the subject of the present notice, I shall adopt the specific name without further parley.

* Decade iii. vol. v. p. 453 (1888).
† Cat. Foss. Rept. Brit. Mus. pt. i. p. 195 (1888).
‡ *Ibid.* p. 227.

In the original description it is stated that the mandible is 29·5 inches in length, of which 9·5 inches are occupied by the symphysis; and that the teeth rapidly decrease in size towards the proximal end of the jaw, in which region they are very small. There remain 18 true cervical vertebræ *, of which the centra are slightly cupped, and the cervical ribs are short and wide. The 19th to the 24th vertebræ are described as 'pectoral,' and comprise those which are transitional between the true cervicals and dorsals, and are characterized by the neurocentral suture descending in a V onto the centrum; while the 25th to the 46th are reckoned as dorsal. With the exception of some remarks on the humerus and femur, the above constitutes the gist of the original description.

Some months ago Mr. G. C. Crick, F.G.S., of the British (Natural History) Museum, brought to my notice a considerable portion of the skeleton of a medium-sized Sauropterygian, obtained from the Oxford Clay of Green-End, Kempston, about three miles south-west of Bedford, which at once struck me as presenting several interesting features. This specimen (which has been presented to the Museum by Mr. Crick, Sen.) I was enabled, during a visit to Cambridge, as already mentioned, to identify with *Plesiosaurus philarchus*. When found, I have no doubt that the skeleton of this example was entire, but it has been sadly broken up during its extraction by the clay-diggers. The portions remaining comprise several upper teeth in very beautiful preservation; the greater portion of the mandible, of which the symphysial region is entire, although the crowns of the teeth have been broken off; a considerable number of vertebræ, mostly from the dorsal, lumbar, and caudal regions; the greater portion of the two pelvic and pectoral limbs, and a considerable part of the corresponding girdles. I have also had the opportunity of examining several more or less nearly entire skeletons of the same species from the Oxford Clay near Peterborough, in the collection of Mr. A. N. Leeds of Eyebury, near that town, which have afforded important aid in determining the true affinities of this species. In the main my description will be based on the Bedford skeleton, but I shall supplement its deficiencies by reference to the other specimens.

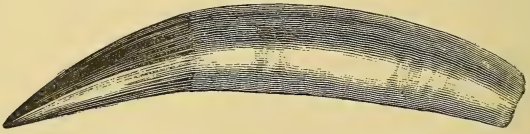
It will save trouble to state at starting that I regard this form as indicating a new genus, for which I shall propose the name *Pelòneustes*.

Commencing the description with the mandible, it appears that on the right side there are 38 teeth, and since the symphysis slightly exceeds 9 inches in length, it will be evident that this specimen accords exactly in these respects with the type. And it may be added that another mandible from the Oxford Clay of Peterborough in the British Museum (No. 47411) also agrees with these dimensions. The first seven mandibular teeth are very large; the eighth is somewhat smaller; while the 9th and following teeth are considerably smaller. Thirteen teeth are included in the symphysis.

* Professor Seeley counts the conjoint atlas and axis as a single vertebra.

The symphysis and portions of the rami of the mandible are shown in Plate II. fig. 1. In its very long symphysis this mandible differs widely from that of the typical Liassic *Plesiosaurus dolichodirus*, in which there are only three or four teeth in the symphysis. In some species of *Plesiosaurus* (using this term in its restricted sense) the symphysis tends, however, to become longer, as is shown in the jaw of *P. rostratus* of Owen, where there appear to be six or seven of these teeth. No *Plesiosaurus* has, however, a symphysis of the length of that in the present specimen, or such a large total number of teeth. In both these respects the form under consideration agrees much more nearly with the type mandible of the genus *Pliosaurus*, figured on page 343 of Phillips's 'Geology of Oxford,' in which there are at least 35 teeth, of which some 12 are included in the symphysis. Further indications of Pliosaurian affinities are, moreover, shown by the teeth themselves, of which an entire specimen from the anterior part of the upper jaw is shown in the accompanying woodcut (fig. 4). The crown of this tooth, in place

Fig. 4.



Upper tooth of *Peloneustes philarchus*. (Nat. size.)

of being regularly conical, with the flutings running continuously from base to summit on all sides, has two distinct carinæ marking off a lateral surface which is less convex than the rest of the crown, and has but very few flutings, or ridges, which are confined to the basal half. On the more convex portions of the crown the flutings also stop short of the summit, and are of the bold type and irregular length characteristic of *Pliosaurus*. Although these teeth are decidedly different from those of the typical form found in *Pliosaurus brachydirus*, yet they closely resemble in structure other Pliosaurian teeth of larger size from the Oxford and, more rarely, the Kimeridge Clay.

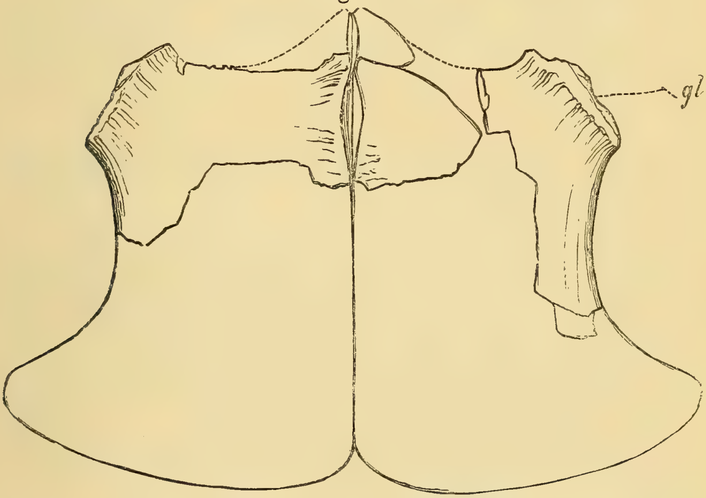
Several teeth from the Great Oolite of Caen, in Normandy, preserved in the British Museum (No. 32608), agree almost precisely in structure with those of the present form, although they are of larger size. Similar teeth from the same deposits were described by Deslongchamps under the name of *Poikilopleuron Bucklandi*; but their Sauropterygian character was pointed out by M. Sauvage*, who referred them to his genus *Liopleurodon*, of which the type species may be included in *Pliosaurus*. I have, however, no doubt that these teeth are really referable to *Thaumatosaurus oolithicus*, a Sauropterygian from the Lower Jurassic of Württemberg, described at a much earlier period by Meyer, of which more anon.

The cervical vertebræ being absent in the Bedford specimen, their

* Bull. Soc. Géol. France, sér. 3, vol. i. p. 378 (1873).

characters must be sought from other examples. In the Cambridge specimen the cervical ribs are anchylosed to the centra, but the attachment is of a deep and subpyramidal form, quite different from that occurring in Jurassic Sauropterygians like the so-called *Plesiosaurus Manseli*, and exhibits indications of the presence of double costal facets in the young. Such double costal facets are shown in the skeleton of two immature individuals in the collection of Mr. Leeds. The cervical centra are short, with slightly cupped terminal faces. The number of cervicals in one of the specimens in the latter collection is 21, which seems to indicate that some are missing in the Cambridge specimen. The dorsal and lumbar vertebræ do not afford any very important characters, although it appears that the neuro-central suture is persistent. Of the pectorals or lumbars of the Bedford specimen an imperfect example is represented in Pl. II. fig. 3, while the centrum of a caudal is shown in fig. 2 of the same Plate, the

Fig. 5.



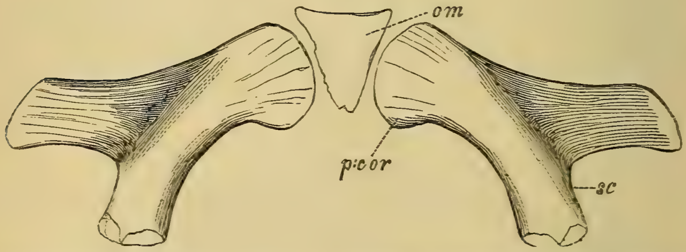
Coracoids of *Peloneustes philarchus*, restored and reduced. *gl.* glenoid facet.

sutural union of the arch with the centrum being well shown in the former figure.

When the specimen came to the Museum the pectoral and pelvic girdles were in a multitude of fragments: but with great patience Mr. Lingard, one of the Attendants in the Geological Department, has succeeded in joining many of these together, so that the general plan of structure can be determined. In the pectoral girdle (in which I follow, in the main, the interpretation of the component bones given by Mr. Hulke in his Presidential Address to our Society in 1883) considerable portions of the two coracoids and scapulæ have been pieced together. The former are placed in their natural position in the accompanying diagram (fig. 5), with an approximate restoration

of the posterior portion. These coracoids closely resemble the corresponding bone of *Pliosaurus Evansi* figured on p. 722 of vol. xxxiii. of the Society's 'Journal,' by Professor Seeley *. The precise contour of the scapulæ in the Bedford specimen cannot be determined, and this deficiency has accordingly been supplemented by fig. 6, which is taken from one of the specimens in the collection of Mr. Leeds. It will be seen from this figure that the ventral plates of the scapulæ were separated in the median line by a very small and triangular omosternum, and that there appears to have been no median bar connecting the former with the coracoids. The contour

Fig. 6.



Anterior part of pectoral girdle of *Peloneustes philarchus*, viewed from the ventral aspect. *om*, omosternum; *sc.*, scapula; *p.cor.*, ventral (precoracoidal) plate of do. (Reduced.)

of the entire scapula is undistinguishable from that of the corresponding bone, commonly and, I believe, rightly referred to *Pliosaurus*, and is quite distinct from that of Liassic species of *Plesiosaurus*. The presence of the omosternum and the absence of the median bar connecting the ventral plate of the scapulæ with the coracoids widely distinguishes this type of pectoral girdle from that occurring in those Jurassic and Cretaceous Sauropterygians which I have recently proposed † to include in the genus *Cimoliosaurus*, which is taken to embrace both *Elasmosaurus* and *Polycotylus* of Prof. Cope, and *Colymbosaurus* and *Murænosaurus* of Prof. Seeley.

In the pelvic girdle there remains one nearly entire pubis, a fragment of the corresponding bone of the opposite side, and the acetabular portion and a large part of the outer border of the two ischia. In regard to the pubis (fig. 7) I have no observation to make. The ischia are very imperfect, but sufficient remains of the specimen, shown on the right side of fig. 8, to indicate the general contour, which is well shown in one of the specimens in the collection of Mr. Leeds. I find an ischium of precisely similar type, although of rather larger dimensions, in the British Museum (No. 47325), from the Kimeridge Clay of Swindon, which has been introduced on the left side of figure 8, although it is probably referable to a distinct

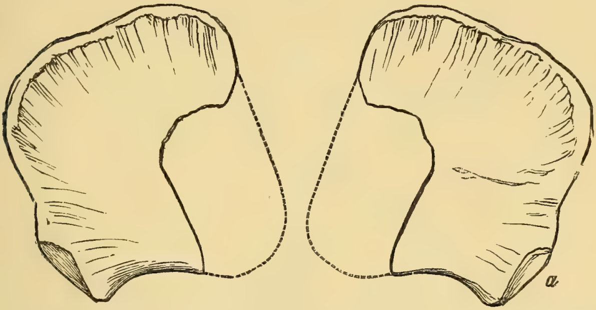
* Originally regarded as an ischium, but redetermined in the Geol. Mag. decade iii. vol. iv. pp. 478–479 (1887).

† Geol. Mag. decade iii. vol. v. p. 356.

species This type of ischium is longer than that of the typical species of *Plesiosaurus*, and is quite undistinguishable from that of *Pliosaurus*, of which there is an enormous specimen in the collection of Mr. M. Fisher of Ely.

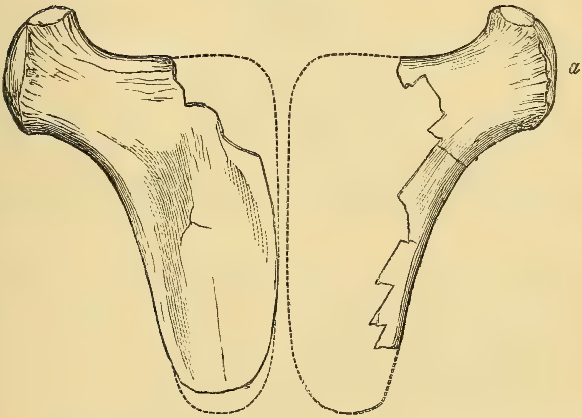
In the limbs, the humerus (fig. 9) and femur respectively articu-

Fig. 7.



Pubes of *Peloneustes philarchus*. (Reduced.) *a*, acetabular facet.

Fig. 8.



Ischia of *Peloneustes*. The specimen on the right side is from the Kimeridge Clay, and that on the left from the Bedford specimen. (Reduced *.)

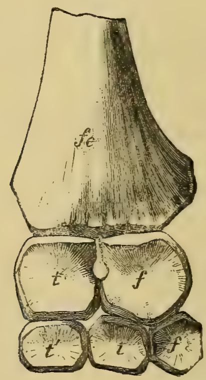
late with only two bones, which still retain evidence of their original character as "long bones," and are separated by a distinct interval.

Having now reached the end of the description of this interesting

* The artist has made an error in this figure, since the specimen on the right should have been restored simply from that on the left, which merely required the reproduction of the antero-internal angle.

form, it remains to consider its generic position. At the time when I first brought the subject of this part of my paper under the Society's notice, I was inclined provisionally to employ the term *Plesiosaurus* in the wide sense in which it has been used by Mr Hulke. Subsequent experience has, however, led me to the conclusion that it is advisable to separate from that genus not only those Post-Liassic forms which I have already incidentally mentioned under the name of *Cimoliosaurus*, but also the present species and certain kindred forms. I shall confine, then, the name *Plesiosaurus* to those Sauropterygians having a neck of considerable length, comparatively small heads and teeth, the cervical vertebræ more or less elongated, and usually with double costal facets and firmly anchylosed arches, and the pectoral girdle with a comparatively large omosternum,

Fig. 9.



Part of pectoral limb of *Peloneustes philarchus*. (About $\frac{1}{8}$.)
fe, humerus; *t*, radius; *f*, ulna; *t'*, radiale; *i*, intermedium; *f'*, ulna e.

formed of two elements; the scapulæ being widely separated in the ventral middle line, with a small and concave ventral surface, and a very large dorsal portion extending throughout the length of the bone, and no median union between their ventral portion and the coracoids. In those forms which I propose to include in *Cimoliosaurus* the neck is usually greatly elongated; the head and teeth are very small; the cervical vertebræ are more or less elongated, with single costal facets, and often complete anchylosis of the arches and ribs with the centra; while the pectoral girdle is devoid of an omosternum, and has the ventral part of the scapulæ very large and flat, and the dorsal part greatly reduced in size, the ventral plates meeting in the median line, and sending down a median bar to join the coracoids, which are produced in the middle in advance of the glenoid cavity. This genus I regard as a branch in one direction from *Plesiosaurus*, while another branch has culminated in *Pliosaurus*. In the latter branch I would place the so-called *Plesio-*

saurus Cramptoni of the Upper Lias, which Prof. Seeley has made the type of the genus *Rhomaleosaurus*, and which is characterized by its enormous head and teeth, short mandibular symphysis, and short neck, in which the vertebræ are comparatively few in number, with short centra, having deeply cupped faces, and carrying double costal facets, and with firm articulation of the arches. The pectoral girdle is unknown in this form; but in the Lower Liassic *Plesiosaurus megacephalus*, as well as in the closely allied *P. arcuatus* of Owen, in which the head and neck exhibit all the generic characters of the so-called *Rhomaleosaurus*, this part of the skeleton is shown. It has an extremely large omosternum, forming a shield-like plate, with a long wide notch on the anterior border, and apparently consisting of a single element; the scapulæ and coracoids being of the general type of those of *Plesiosaurus*. Mention has already been made of the large Sauropterygian founded upon vertebræ and teeth from the Great Oolite, to which the name *Thaumatosaurus oolithicus* has been applied; and a comparison of the figures of these specimens with *Plesiosaurus Cramptoni* fails to show even a specific distinction between the two, although this might be indicated if fuller materials were available. Since, therefore, I fail to see any characters by which *Rhomaleosaurus* can be distinguished from *Thaumatosaurus*, I can but include the former in the latter genus. The cervical vertebræ of *Thaumatosaurus*, although they agree with those of the present form in their short centra and double costal facets, are distinguished by their deeply cupped, in place of nearly flat, terminal facets, and are thereby also distinguished from those of *Pliosaurus*. Vertebræ of the type of those of *Thaumatosaurus* occur from the Lias to the Kimeridge Clay, the species of the latter horizon having been long ago described by Cuvier as *Plesiosaurus carinatus*. With regard to the generic position of the species forming the subject of this communication, I may observe that before I had satisfied myself as to the difference of its cervical vertebræ from those of *Thaumatosaurus*, and also as to the nature of the pectoral girdle of any of the species which I include in the latter, I considered* that the species in question might enter that genus, since I did not regard the elongated mandibular symphysis as necessarily indicative of generic distinction. The pectoral girdle of *P. arcuatus* is, however, so totally different from that of the Oxfordian form that I can no longer maintain this view; especially with the concomitant difference in the cervical vertebræ. I cannot, moreover, very well include the present form in *Pliosaurus*, from which it is distinguished by the firm articulation of the arches with the centra of the vertebræ, and the longer epipodial bones; and I therefore—much as I dislike proposing new generic terms—feel bound to refer it to a new genus, for which I think the name *Peloneustes* will be appropriate. The Kimeridgian vertebra to which Professor Seeley has applied the name *Plesiosaurus sterrodirus* will belong to the same genus, and also the femur described by Phillips as *P. æqualis*.

* Geol. Mag. decade iii. vol. v. p. 353 (1888).

This genus forms a link connecting other forms with *Pliosaurus*, and will be characterized by its comparatively short neck, large head and carinated teeth, elongated mandibular symphysis, short cervical vertebræ, having double costal facets and flattened terminal faces, with complete anchylosis, in the adult, of the arches and ribs with the centra. In the pectoral girdle there is a small omosternum; the scapulæ have a flattened and large ventral surface, the dorsal portion being smaller than in *Thaumatosaurus*; and the coracoids have no distinct median production in advance of the line of the glenoid cavity. In the limbs the epipodials are less elongated than in the last-named genus. Finally, *Pliosaurus* itself is distinguished by its still larger head and teeth; the still shorter neck, in which the vertebræ are less elongated and more flattened, the costal facets are more distinctly double, and the arches and ribs unite merely by synchondrosis with the centra. The pectoral girdle is of the same general type; but the omosternum may have been totally lost. Both genera have similarly elongated ischia; but the epipodials of *Pliosaurus* have become so shortened as to lose all resemblance to "long bones."

With the evidence of *Peloneustes* before us we now have an almost continuous chain connecting the genus *Plesiosaurus* with *Pliosaurus*, the course of evolution being directed towards a gradual increase in the size of the head, in the length of the mandibular symphysis, and the size and specialization of the teeth, accompanied by a shortening of the neck, which is accomplished by a reduction both in the number and length of the component vertebræ, and also by a tendency to a loose attachment between the centra, arches, and cervical ribs of the vertebræ, and a reduction in the relative length of the epipodial bones of the limbs. That *Peloneustes philarchus* is the direct ancestor of *Pliosaurus* is, however, improbable, seeing that the latter genus is already represented in the Oxford Clay. Finally, while *Pliosaurus* forms the culmination of the series just indicated, the genus *Polyptychodon* appears to have been the latest development of the series of which the middle term is represented by *Cimoliosaurus*.

V. The Affinities of Geosaurus.

In a recent number of the 'Geological Magazine'* I have shown that the genus *Geosaurus*, from the Lower Kimeridgian of Bavaria, is undoubtedly a Crocodilian allied to *Metriorhynchus*; and a skeleton of the latter genus from the Oxford Clay near Peterborough, lately sent by Mr. A. N. Leeds to the Natural History Museum, has enabled me to make a closer comparison between the two, of which a summary is now given. First, it appears from several skeletons in the collection of Mr. Leeds, as well as from the type of *Geosaurus*, that these Crocodiles have no dermal scutes, but that bony plates were developed in the sclerotic of the eye. The

* Decade iii. vol. v. p. 452 (1888).

structure of the pelvis of *Metriorhynchus* * is very peculiar, and with the aid of the above-mentioned skeleton the three elements of this girdle can readily be detected, in a somewhat imperfect condition, in the slab containing the hinder portion of the type of *Geosaurus*, these bones corresponding in all respects with those of *Metriorhynchus*.

There appears, moreover, to be no doubt that some of the skulls described by Wagner under the name of *Cricosaurus*, which were obtained from the same Lower Kimeridgian horizon as *Geosaurus*, are identical with that genus; although one of them, I believe, belongs to *Metriorhynchus*. These specimens, together with a skull in the Natural History Museum, show that there was no lateral vacuity in the mandible of *Geosaurus*, and that the upper surface of the skull was almost or quite devoid of sculpture. The teeth, as shown by several specimens, have laterally compressed crowns bearing a pair of well-defined carinæ, which are marked by fine serrations, their lateral surfaces being smooth and polished.

In *Metriorhynchus*, on the other hand, as I gather from Mr. Leeds's examples and those figured by E. Deslongchamps, the upper surface of the skull is more or less distinctly sculptured; the mandible, at least frequently, has a lateral vacuity: while the teeth have subcylindrical crowns, without distinct carinæ, and with the enamel marked by longitudinal rugosities.

These differences would appear to indicate the right of *Geosaurus* and *Metriorhynchus* to stand as distinct, although closely allied, genera. If, however, the genus *Dacosaurus*†, which is likewise of Kimeridgian and Oxfordian age, be compared with *Geosaurus*, it appears that no characters can be detected by which the two are distinguishable. Thus the skull has the same absence of sculpture; the mandible, as Mr. Hulke has shown, has no lateral vacuity; and the structure of the teeth is identical. We have, indeed, no evidence as to the presence of sclerotic plates, but the absence of scutes is very noticeable in the imperfect skeleton described by Mr. Hulke. In the absence, therefore, of any apparent distinction, I think the genus *Dacosaurus* must be merged in the earlier *Geosaurus*, in which the type species was originally placed by Plieninger.

The Metriorhynchinæ, or Geosaurinæ, will therefore be a subfamily of the Teleosauridæ, containing the genera *Geosaurus* and *Metriorhynchus*, and typically characterized, in addition to the features pointed out in the diagnosis given in the 'Catalogue' above cited ‡, by the absence of dermal scutes and the presence of sclerotic plates. *Crocodilæmus* of Jourdan § has a well-developed armour, and is therefore entitled to distinction from *Metriorhynchus*; but

* An interesting paper on the skeleton of *Metriorhynchus* has been recently read by Mr. Hulke before the Zoological Society.

† Including *Steneosaurus Manseli*, Hulke, = *Plesiosuchus*, Owen. See the writer's 'Catalogue of Fossil Reptilia and Amphibia in the British Museum,' pt. i. p. 92 (1888).

‡ Page 91. § *Ibid.* p. 98.

whether it should remain in the same family cannot be determined until the characters of the skull are fully known.

Before leaving this subject it is well to call attention to the circumstance of the absence of dermal scutes in this group of Crocodiles being accompanied by the development of sclerotic plates, although I am unable at present to assign any reason for this correlation.

EXPLANATION OF PLATE II.

Peloneustes philarchus (Seeley), from the Oxford Clay near Bedford.

Fig. 1. Palatal aspect of greater part of mandible. $\frac{1}{5}$ nat. size.
2. Posterior aspect of centrum of caudal vertebra. *c*. Chevron-facet. Nat. size.
3. Terminal aspect of imperfect pectoral or lumbar vertebra. Nat. size.

Discussion.

Prof. Seeley remarked that the difficulties presented by such materials as were before the Society would justify great caution in accepting the interpretation offered, and he was not prepared to offer serious criticisms without having the materials before him on which they might be based. It was probable that *Syngonosaurus*, formerly referred to the Dinosauria, belonged to the group which he preferred to name Ornithischia. He was glad to find that the Author was disposed to separate the *Iguanodon Prestwichii* from the genus to which it had been referred. If the femur of which a cast was exhibited was referable to the same species, it fully justified that conclusion; but nothing was known of the femur of *Camptosaurus* from specimens in this country, and he would only mention the opinion given generally by Prof. Marsh that no American genus of Reptiles could be with certainty identified as occurring in Britain. He thought the characters which had been pointed out made it convenient to refer the type of *Iguanodon Prestwichii* to the genus *Cumnoria*.

The Plesiosaurians were first divided by Cope into two families on characters drawn from the shoulder-girdle. Prof. Seeley had found further modifications in the Reptiles of this country to which generic names had been given, because the vertebral column, the limbs, and, in some cases, the skull furnished confirmation of their generic differences. He might remark that, after studying the types of Von Meyer's genus *Thaumatosaurus*, he was convinced that both in the teeth and in the vertebral characters it is identical with *Pliosaurus*. But *Pliosaurus* varied so much in its different representatives that he was not prepared to say that every Pliosaurian reptile belonged to the genus *Pliosaurus*. Whether the genus *Peloneustes* was distinct from types already described might require consideration, but he believed that further research would sustain the genera of Plesiosaurians which he had already established.

The Author, in reply, observed that, immediately before departing for America, Prof. Marsh informed him that he regarded certain

Wealden remains in the British Museum as referable to the American genus *Morosaurus*, and that he also considered *Omosaurus* (preoccupied) inseparable from *Stegosaurus*—with both of which conclusions the Author concurred. In referring the femur described above to *Camptosaurus*, the Author stated that, as he could find no points of distinction, he followed his usual rule of regarding forms as generically identical until they could be proved to be different, in preference to the opposite course.

With regard to the statement that *Thaumatosaurus* should be included in *Pliosaurus*, the Author mentioned that the former was from the Great Oolite; and observed that if that view was maintained it would be necessary to include in the same genus the species (*Plesiosaurus Cramptoni*) on which *Rhomaleosaurus* was founded, as well as other allied types with a short mandibular symphysis and a peculiar type of pectoral girdle, and also the form described above as *Peloneustes,* all these forms having more or less triangulated teeth. The points on which the Author differed from Prof. Seeley in regard to the so-called Elasmosaurians were merely ones of degree, the Author preferring to use a generic term in the sense in which Professors Cope and Seeley employ a family one.

3. *On* Fulgurites *from* Monte Viso. By Frank Rutley, Esq., F.G.S., Lecturer on Mineralogy in the Royal School of Mines. (Read December 5, 1888.)

[Plate III.]

The specimens described in this paper were collected within six or seven feet of the summit of Monte Viso (about 12,680 feet above the sea-level) by Mr. James Eccles, F.G.S., who kindly forwarded them to me for examination.

The larger one, fig. 1, Pl. III., is a piece of compact bluish-grey rock, about 6½ inches long by 1¾ inch in its greatest breadth. In one part it shows a delicate banding, the direction of which is indicated by an arrow, *b*, placed on the left of the figure. This banding, however, is not distinctly visible on the surface represented, although it is well defined on the back of the specimen, which is bounded on one side by a smooth joint-plane, *c c*, upon portions of which a thin crust of fulgurite-glass has been formed. The outer surfaces are far less even; but if not actually joint-planes, they have, at all events, been directions of easy fission, suggestive of a system of intersecting joints, and these, in several parts, are incrusted with minute pellets and thin films of fulgurite-glass.

The surface shown in fig. 1, Pl. III. (natural size), has been ploughed out by lightning, the track being marked by curved and branching, hemicylindrical furrows, *a a*, varying from about ½ inch to $\frac{1}{32}$ inch in diameter.

These tubes are lined with a thin crust of dark brown, vesicular fulgurite-glass, and one of the smallest branches of the longest tube is completely filled with this substance. The approximate thickness of the glassy lining of part of a tube is shown in fig. 2, Pl. III., while the slaggy and vesicular character of the vitrified surface is represented in fig. 3, Pl. III., as seen under a very low magnifying-power, where *a a* represents a portion of one of the lightning-tubes with its glassy lining; *b*, a delicate band in the rock due to foliation, and *f* some minute grains of fulgurite-glass adhering to the surface of the rock and situated at a slight distance from the left wall of the tube. This drawing was made from a specimen considerably smaller than the one first described, and it shows only part of a single tube having an average diameter of ⅓ inch.

Before describing the microscopic characters of the fulgurite-glass it may be well to give some account of the mineral constitution of the rock from which, through fusion, the glass has been formed.

When a thin section of this rock is examined under the microscope, a general schistose and, in places, an almost fibrous-looking structure is visible, due to an intimate admixture of glaucophane and epidote, the former of a pale blue, the latter of a pale yellowish colour.

The glaucophane appears, as a rule, in imperfectly developed

prisms, seldom, if ever, showing any distinct terminal faces; while much of it seems to consist of minute grains and extremely small prisms, mixed with a considerable amount of epidote. The angle of the prism in one or two sections of glaucophane, taken transversely to the vertical axis, was similar to that of hornblende, 124° to 125°. In orthopinacoidal sections, apparently those chiefly seen in the slides which have been prepared, the pleochroism is well marked, vibrations parallel to $\mathfrak{c}$ = pale yellowish-green to greenish-blue, while those parallel to $\mathfrak{b}$ = lavender-blue, the absorption being $\mathfrak{c} > \mathfrak{b}$, as in the glaucophane of Ôtakisan in Japan described by Prof. B. Kotô *.

The extinction-angle in a clinopinacoidal section, measured with a Bertrand's stauroscope-ocular, is about 5° only. The prisms are very commonly traversed by transverse fissures, as in actinolite. In one or two of the slides a little diallage occurs, sometimes enclosing numerous crystals of glaucophane, so that the extinction-angle cannot be clearly ascertained; some small patches of diallage, however, appear to extinguish at an angle of about 39° to the direction of the characteristic separation-planes or cleavages (*i. e.* to ∞ P ∞ or 100). The mineral is of a pale-greenish tint, exhibits scarcely a trace of pleochroism, and shows no definite crystallographic boundaries.

In most, if not in all, of the sections prepared from this rock numerous little crystals are present, which are either partially or wholly opaque, and which, where they transmit light, appear of a more or less deep brown colour. Their partial or entire opacity is due to the presence of a decomposition-product, which, by surface-illumination, is seen to be white. Owing to the prevalence of this opaque matter the character of the pleochroism cannot be made out.

These crystals appear, in section, mostly as very acute rhombs, of which the obtuse angle ranges between 130° and 140°. The mean of five careful measurements gave 135° 36′. It seems therefore very probable that these crystals are sphene in an advanced stage of alteration. One measurement gave 136° 15′, which is almost the angle between the faces $\frac{2}{3}$ P 2, or $\bar{1}23 : \bar{1}\bar{2}3$ in sphene, while several others gave approximately 133°, which is nearly the angle of the prism. It would be unsafe, however, to attach much importance to these measurements, since, owing to the opacity of the crystals, it is impossible to determine, by means of optical characters, in what directions they are cut †. The epidote present in the rock occurs mostly in small, irregularly shaped or rounded grains, seldom in distinct crystals.

A very striking feature in sections of this rock is the presence of crystals of garnet, which, viewed by transmitted light, appear nearly colourless or of pale yellow or yellowish-green tints. They are, for the most part, of very irregular form, are strongly fissured, and seldom show any definite crystallographic boundaries, although occasionally

* "A Note on Glaucophane," Journ. Coll. Sci. Imp. Univ. Tōkyō, vol. i. pt. 1, p. 4.

† Dr. F. H. Hatch, to whom I have since submitted the sections, is also inclined to regard these crystals as altered sphene.

sections are seen which may be referred to rhombic dodecahedra. They are isotropic.

From the foregoing observations it appears, therefore, that the rock is a glaucophane-epidote schist in which garnet, sphene, and occasionally diallage are present.

Fig. 1 shows the general appearance of a section of this glaucophane-schist, as viewed in ordinary transmitted light and magnified 120 linear. The large irregularly shaped crystals are garnet, the brown and partly opaque crystals, of which two are shown at the bottom of the figure, are sphene, while the remainder consists of blue glaucophane and yellowish or yellowish-green epidote.

Professor Judd considers that the rock somewhat closely resembles the glaucophane-schists and eclogites of the Ile de Groix, off the coast of Brittany, described by Dr. Barrois. In the association of glauco-

Fig. 1.

Glaucophane-Schist, × 120.

phane with epidote it also resembles the glaucophane-schist described by Professor Kotô, to whose kindness I am indebted for specimens of the Ôtakisan rock. It is also possibly allied, to some extent, in mineral constitution to the glaucophane-eclogite of the Val d'Aoste, described by Professor Bonney *.

The summit of Monte Viso is stated by Studer to consist of serpentine; but, prior to any microscopic examination of the rock, Mr. Eccles expressed his belief that it was probably what Prof. Studer had described as "*grüne Schiefer*," and certainly not serpentine, although Mr. Eccles remarks that serpentine is not unfrequently associated with the "*grüne Schiefer*."

I have to thank Professor Judd for kindly allowing sections from

* Mineralogical Magazine, Dec. 1885.

these specimens to be made in the Science Schools at South Kensington, and Mr. Chapman has been most successful in the exceedingly delicate and difficult operation of preparing slices of the rock with portions of the fulgurite-glass adhering to the surface.

Having described to some extent the nature of the rock itself, these vitreous incrustations will now claim our attention. Before the sections were prepared, a few small pellets of fulgurite-glass were scraped from the surface of one of the specimens, crushed, and examined under a quarter-inch objective. Two rod-like microliths (longulites) were first observed in a small fragment of glass which was picked with the point of a knife from one of the surfaces, either of fracture or rough cleavage, on the larger specimen, fig. 1, Pl. III. These microliths were, when first seen, situated at a slight distance from one another; but, owing to the viscidity of the balsam in which they were mounted, it was found that after an hour or more the smaller one had shifted its position, so as to come in contact with the larger microlith. Evidently, then, one of these rod-like bodies was free to move, and was not imbedded in the glass-fragment, a circumstance which necessarily raised the question whether the other was also unattached.

Another small sample was consequently taken, also from a fractured surface of the rock, and crushed, so that the fragments might be thin enough for microscopic examination. Here, again, microliths appeared, not only on or in the fulgurite-glass, but also in considerable numbers in the fine powder which resulted from the crushing of the fragments.

Thinking it might be possible that they belonged rather to the rock itself than to the actually fused rock-matter, another minute pellet of fulgurite-glass was removed, and, on examining it with a lens, a small quantity of the rock was found adhering as a film to the surface of the pellet where it had been detached.

To avoid any such source of error, a very small blister of fulgurite-glass was removed from the interior of one of the lightning-tubes (*a*, fig. 1, Pl. III.), where the lining of vesicular glass was sufficiently thick to insure perfect isolation of the glass from the rock. This, when crushed and examined under a power of about 250 diameters, showed that the glass is, as a rule, remarkably pure, but that not only gas-bubbles but globulites occur in it, in places, and these occasionally form margarites and longulites, some of the rod-like bodies which come under the last denomination distinctly exhibiting double refraction. A few of the better-formed examples can be proved to lie *within* the fulgurite-glass, since adjacent globulites can be brought into focus both above and below them.

I have taken especial pains to verify this point, since, so far as I know, this is the first instance of the occurrence of crystallites in fulgurite-glass which has hitherto been recorded. In these specimens the globulitic and longulitic conditions are frequently visible, but the margaritic stage is not so common. Adopting Vogelsang's terminology, all of these bodies would be included under the name of crystallites. A longulite and some globulites are shown in fig. 4,

Pl. III., as seen under a magnifying-power of 250 linear. Fig. 5, Pl. III., shows a few margarites, selected from different fragments, while fig. 6 gives a fair idea of the vesicular character of the fulgurite-glass, as seen in a fragment taken from the interior of one of the lightning-tubes and magnified 120 linear. Fig. 7 represents a microlith imbedded in a fragment of fulgurite-glass. This microlith shows distinct double refraction, and the direction of maximum extinction makes an angle of about 16° to 17° with the longest axis.

In a thin section of excessively vesicular fulgurite-glass taken from the specimen represented in fig. 1, Pl. III., there are some good examples of microliths which exhibit very distinct double refraction; some of them appear to show parallel, and others oblique extinctions, the latter giving an extinction-angle of 15° to 20° with the longest axis. That both those showing parallel and those giving oblique extinctions are identical seems highly probable, their apparent differences in this respect being most likely due to the positions in which they lie in the section. That some of them are clinometric is certain. That they are all clinometric is probable. In this section globulites are also plentiful. They occur either singly or in lines (margarites) composed of several globulites, occasionally five in number. Besides these linear groupings other arrangements are also seen—groups of three globulites massed trefoilwise, as in fig. 8 *b*, Pl. III., are not uncommon, while less frequently cruciform groupings, similar to that represented under *a* in the same figure, may be seen. The fulgurite-glass, when viewed by transmitted light, ranges from a tolerably deep coffee-colour to pale yellowish-brown or almost colourless, according to the thickness. The vesicles in the glass are, as a rule, perfectly spherical, and in some instances so numerous and closely packed that the glass is quite spongy in character.

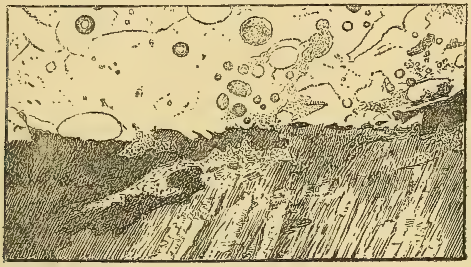
Where the fulgurite-glass comes in contact with the rock the latter appears to have undergone no appreciable alteration beyond the development of a very narrow band of opaque, white matter, resembling the substance of the altered crystals of sphene which the rock contains. The band is exceedingly variable in thickness, and occasionally thins almost entirely away, as shown in the dark irregular belt which crosses fig. 2, where the upper portion of the drawing represents the crust of vesicular fulgurite-glass lining one of the lightning-tubes, while the lower portion shows the rock (×120 linear). In one section a minute, rounded grain of schist, containing a fragment of a strongly depolarizing crystal, probably epidote, appears to have been taken up in the fulgurite-glass.

As regards the opaque white band, already mentioned as occurring at the junction of the glass with the rock, I am much more disposed to think that it is due to the presence of altered sphene than to any alteration of the rock-surface induced by the action of lightning; for a line drawn through other parts of the section might easily pass through crystals and segregations of similar white matter of like extent and continuity. If it were an alteration-product engendered suddenly by an intense heat we should rather expect

to find the rock altered to a uniform depth around the lightning-tube *.

Throughout this paper I have spoken of these ramifying, vitrified grooves as *tubes*, because it is my impression that the lightning did not produce these channels upon the exposed surfaces, but actually penetrated the rock; and Mr. Eccles informed me that he saw one of these tubes penetrating the rock *in place*; unfortunately, however, the difficulty of detaching the piece of stone, without crushing the tube, prevented him from securing this most interesting specimen. Lightning-tubes more than an inch in diameter, penetrating an andesitic rock on the summit of Little Ararat, have also been described by Abich as far back as 1870 †. I think it may therefore be taken for granted that these ramifying channels are portions of tubes laid open to us in section by the rock having been split along planes of easy fission.

Fig. 2.



Contact of Fulgurite-Glass with Glaucophane-Schist.

Another interesting problem presents itself in the occurrence of minute glassy pellets and thin vitrified crusts on these joint-planes and fractures. Their existence is, I think, to be accounted for, if we assume that the lightning as it penetrated the rock also split and shattered it, preferably in the direction of pre-existing structural planes, and, just as a flash may be seen to emanate from the breech-joint of a rifle when fired in the dark, so we may conceive that the flash of the lightning penetrated, and actually prized open, the joint-planes in the neighbourhood of the tubes which it formed, in this instance fusing the surfaces along which it passed.

The occurrence of globulites, margarites, longulites, and microliths in the fulgurite-glass would seem to indicate a less sudden cooling of the fused matter than is assumed to be usual in such

* There are, however, peculiar contact-phenomena to be observed sometimes where tachylytic glass comes against a rock-surface, and it is just possible that this may be a similar case. *Vide* "Some Additional Occurrences of Tachylyte," by Grenville A. J. Cole, Quart. Journ. Geol. Soc. vol. xliv. p. 301.

† Sitzungsb. d. Akad. Wiss. Wien, vol. lx. p. 155.

cases; but, be this as it may, these bodies appear, unquestionably, to have been formed during the refrigeration of the fulgurite, the glass presenting none of the signs which would characterize a subsequent devitrification or secondary change. It must be confessed, however, that we know as yet nothing of the manner in which fulgurite-glasses would undergo devitrification; but, judging from the mineral constitution of this rock, it is possible that we might look for somewhat similar changes in a tachylyte.

EXPLANATION OF PLATE III.

Fig. 1. Specimen of glaucophane-epidote schist, containing garnet, altered sphene, and occasionally a little diallage, from Monte Viso, Cottian Alps. *aa.* Lightning-tubes split open along a joint-plane or uneven plane of easy fission. The tubes are lined with a dark-brown glass. *b.* Arrow indicating the general direction of banding or foliation in the specimen. *cc.* Trace of a smooth joint-surface. Natural size.

2. Section of part of a lightning-tube, showing approximate thickness of the glassy lining. Natural size.

3. *aa.* Portion of a lightning-tube, showing the slaggy, vesicular character of the vitreous lining. *b.* Narrow band, due to foliation and lying in a direction approximately at right angles to that of the lightning-tube. *f.* Minute pellets of vitreous matter adhering to the rock, and situated not far from the wall of the tube. × between 2 and 3 diameters.

4. Fragment of fulgurite-glass, containing globulites and longulites. × 250 linear.

5. Margarites selected from different fragments of fulgurite-glass in which they occur. × 570 linear.

6. Fragment of vesicular fulgurite-glass, broken from the lining of one of the lightning-tubes. × 120 linear.

7. Doubly refracting microlith in fulgurite-glass. (Oblique extinction between 15° and 17° from the longest axis.) × 570 linear.

8. *a* and *b.* Groups of globulites occurring in a section of fulgurite-glass. × 570 linear.

Discussion.

Mr. Eccles agreed with the Author's observations concerning the mode of production of the tubes, which were produced at the same time that the two surfaces were sundered. As regards the absence of glass in parts of the tubes, he considered it might be due to weathering.

F. Rutley del. F. H. Michael lith.

Mintern Bros. imp.

FULGURITES FROM MONTE VISO.
12580 FEET

4. NOTES *on two* TRAVERSES *of the* CRYSTALLINE ROCKS *of the* ALPS.

By T. G. BONNEY, D.Sc., LL.D., F.R.S., F.G.S., Professor of Geology in University College, London, and Fellow of St. John's College, Cambridge. (Read December 5, 1888.)

INTRODUCTION.

IN the address which I delivered at the Anniversary Meeting of the Society in 1886, I gave a brief outline of some investigations into the petrology and structure of certain districts of the Oberland, Pennine, and Lepontine Alps. These had led me to conclusions which were then stated, and had further indicated to me the principal types of rock recognized by the Swiss geologists, and enabled me, as it were, to translate into stone one of their maps. I then determined to make two traverses of the Alpine chain at distances remote from the central portion (the scene of my previous work) and from each othar, so as to acquire a knowledge of the rock-types employed in mapping by geologists outside the Swiss Republic, and compare the crystalline schists or gneisses of these regions with those already known to me. The points, I may again mention, on which I was specially seeking for light were (1) the relation of foliation to pressure, stratification, &c., or, in other words, the history of the genesis of gneisses and schists; (2) the value of the apparent stratigraphical succession which I had observed over a considerable district of the Swiss Alps.

For these purposes it was requisite that any section examined should fulfil, as nearly as possible, the following conditions:—

(1) It should run in a fairly straight line as nearly as might be at right angles to the apparent strike of the rocks.

(2) It should exhibit a seeming succession as extensive as possible.

(3) It should avoid, as far as possible, snowfields, glaciers, alps, and cultivated lands, so as to exhibit fairly continuous exposures of rock *in situ*.

(4) Travel should not be difficult.

These conditions are usually best satisfied by ascending valleys rather than ridges, and crossing passes of moderate elevation.

My Alpine wanderings during the last seven-and-twenty years had given me a general knowledge of the geology of the whole region from the Viso to the Glockner, and, after a careful consideration of the question, and consultation with my friend the Rev. E. Hill, who had again promised to give me the pleasure of his society and the advantage of his cooperation, we decided to take the one section between Grenoble and Turin, and the other slightly west of the Glockner from the Pusterthal northwards. The former section was, indeed, open to some objection, for I knew that the northern part of the Dauphiné *massif* was rather monotonous, petrologically speaking, in its character, and that a great infold of later Palæozoic and Mesozoic rock occurred at the head of the Durance valley, just where an exposure of the crystalline series was particularly desirable. But I also knew that any line of section, either north or south of the glens traversed by the highroad of the Lautaret, would have drawbacks no less serious, while in this there were several compensatory advantages.

The section of the Eastern Alps obviously fulfilled all our conditions, for it lay well to the east of the Tyrol, and crossed all the principal types indicated by colours in Von Hauer's map. These once learnt, it became easy to connect with Switzerland through the Graubünden region, which was to some extent included in the maps of both countries.

Our study of the Alps, of course, has been comparatively superficial. Such an admission in these days of careful surveying and elaborate petrographical investigation may, at first sight, seem to be a sufficient condemnation. But I have seen enough of both methods of working to know that each has its place, and, further, that for my special purpose a minute research would be of little avail, possibly of some harm. The naturalist who stopped to elaborate a memoir on the orchids, would probably fail to give us a good idea of a South-American forest; nay, might even persuade himself that its vegetation consisted mainly of epiphytes. Hence it has been my endeavour in the Alps to become familiar with as large a series of rocks as possible, though neither time nor pains has been spared in working out details when these promised to throw light on the origin of a rock or the history of its structures. Extensive collections were out of the question, owing to the trouble and expense

of transport; but we were careful to bring away examples of all important types, many of which have been since examined microscopically, so far as was necessary for my purpose. In regard to the latter I have only entered into details where they seem to be of interest in relation to the history of the rock, and these, in order not to interrupt the continuity of the text, are given, if brief, in a footnote, if more lengthy in an appendix *.

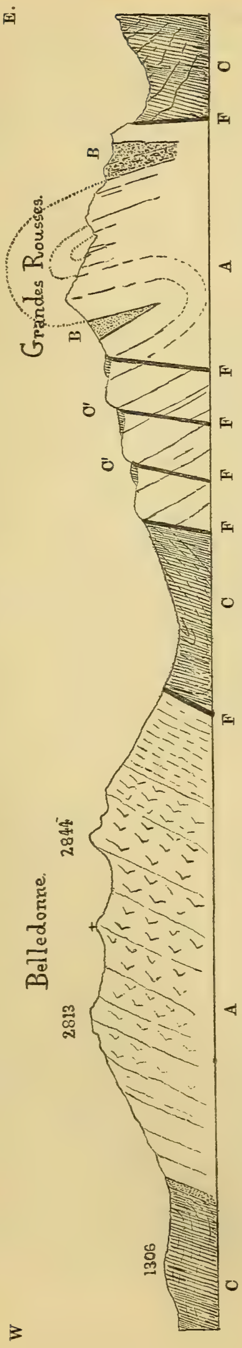
I. The Western Alps from Grenoble to Turin.

A. *Grenoble to Briançon.*

If we take a geological map of the Western Alps, that is of the region south of the valley of the Rhone, restricted for our present purpose by prolonging the part of that valley between Martigny and the head of the Lake of Geneva to the plain of Piedmont in a S.S.E. direction, and by a line drawn roughly from Saluzzo to Gap, we see that a broad belt of crystalline rock runs, almost without interruption, in a general direction rather W. of S.S.W. from the valley of the Rhone until, in the neighbourhood of Vizille (a few miles from Grenoble), it curves towards the S.E. to form the crystalline massif of the High Alps of Dauphiné. The outline of this crystalline mass (something like a pistol, of which the eastward *massif* is the butt) is interrupted in more than one part by patches of Mesozoic or late Palæozoic rock, which usually occur in long strips, running parallel to the general trend of the crystalline rocks. Thus the last really consist of two or three parallel ridges, between which non-crystalline and indubitably sedimentary rocks are infolded. These also fringe the crystalline mass to the west, east, and south (where also some Tertiary rocks occur). The Palæozoic strata (Carboniferous)

* I have not attempted, though it is becoming customary, to devote a section to the literature of the subject. This omission is due to two reasons: the one, that the list would be of formidable length; the other, that it would include a number of papers which, owing to the special end in view, I have not found it needful to consult. Indeed I have referred sparingly even to papers relating to the crystalline series, because, in the present state of the subject, one must know what may be called "the personal equation" of the writers before one can make use of their statements or form any idea, when they are at issue, which of two contradictory conclusions one would be likely to accept if one could personally examine the evidence. But, once for all, I may express my great indebtedness to Prof. Lory, whose classic work, 'Description Géologique du Dauphiné,' has for years past been a valued possession, though occasionally I may be found to differ from his conclusions; to Prof. Favre for his 'Recherches Géologiques dans les Parties de la Savoie, du Piémont et de la Suisse voisines du Mont Blanc;' to the geologists of Switzerland for their admirable map and the associated memoirs; and to Ritter von Hauer for his geological maps of the Tyrol, the merits of which are noticed hereafter. My plan of work, however, has been to consult books only so far as to ascertain their general conclusions and the best localities for work, and then to provide myself with maps rather than with literature. This paper very likely contains few observations which have not been already made; but I am not aware of any one which has been written with quite the same end in view, viz. the attempt to apply a rather wide experience to the interpretation of a somewhat extensive series of sections.

Fig. 1.—*Diagrammatic Section of ranges of Belledonne and Grandes Rousses, after Lory.* (Altitudes in metres.)



A. Crystalline rocks.
C'. Outliers of Lias on the Crystalline rocks.
B. Infolds of Carboniferous group.
C. Lias.
F F. Faults.

are, in this region, generally very limited, and, perhaps, were never very extensive; but the occurrence of the Mesozoic (Triassic and Jurassic) in many isolated patches indicates that they formerly covered the greater part, if not the whole, of the crystalline series*.

Restricting our attention to the Mesozoic rocks only, we find, as we proceed eastward from Grenoble (fig. 1), first the crystalline range of the Belledonne, then the fairly broad Mesozoic infold, traversed by the Olle, but prolonged far away northwards and for a considerable distance in the opposite direction; then the crystalline range of the Grandes Rousses, narrower but loftier than that just named, which is banded on its eastern side by a narrow trough of Secondary rocks, an offshoot from that last mentioned, in the neighbourhood of St. Jean de Maurienne; and after that comes the huge *massif* of the High Alps of Dauphiné, fringed on the north by the same Jurassic rocks, through which it has been violently forced. To the east of the region just described comes another tract of crystalline rock, which forms the watershed of the chain of the Western Alps, up to the southern end of the Mont-Blanc range, together with the mountain region draining to Italy.

The last, as indicated by a geological map, consists almost entirely of a group of schists different in character from those already mentioned (though here and there tracts of the former type occur,

* For further remarks on the subject see the notice by Prof. C. Lory in "Etudes sur les schistes crystallines," read at the Congrès géologique international, 1888 (Sept.), and three lectures given by myself in May 1888, at the Royal Institution, published in the 'Alpine Journal,' 1888–9.

especially in the neighbourhood of the Italian plain), together with green schists, more or less serpentinous in character, and, occasionally, of true sedimentary rocks.

Thus our first traverse was divided into two well-marked portions: the one the crystalline series cut by the Romanche between Vizille and the Col du Lautaret, the other the Franco-Italian range between Briançon and the plain of Piedmont.

The former of these, as above stated, admits of further subdivision into the Belledonne range, the Grandes-Rousses range, and the Dauphiné massif. I may add that, in addition to my general acquaintance with all this region, I have been able to refresh my memory and enlarge my knowledge by the examination of a most interesting series of specimens from its higher peaks and passes, collected by the Rev. W. H. B. Coolidge, Fellow of Magdalen College, Oxford, and presented by him to the Alpine Club.

(*a*) *From Vizille to Bourg d'Oisans: Belledonne Range.*

After considerable hesitation I decided to examine the natural section which is made by the Romanche in cutting through this chain. Although its course makes a very oblique angle with the general trend of the chain, and, from a variety of causes, I was not able to examine this district so carefully as the rest, I believe that I succeeded in ascertaining the dominant types of rock. The first crystalline rock seen is at the Octroi boundary, a short distance from Vizille. It is a hard, darkish brown mica-schist, often evidently considerably corrugated, not very fissile, or markedly bedded or foliated, and rather irregularly jointed (Appendix, p. 100). Rock of this type continues for some distance; then a little beyond Séchilienne it is succeeded by a greener and more distinctly bedded micaceous and somewhat fine-grained rock, the lines of mineral banding and foliation being approximately horizontal; but as this has probably been modified by subsequent pressure, it is difficult to pronounce on its true nature. West of Les Clavaux the rock becomes more like a fine-grained granite, having a slightly gritty aspect on the weathered surface *. There is also a little of a "porphyroid," no doubt an intrusive felstone, modified by subsequent pressure †. Below Rioupéroux fallen blocks of a darkish, massive, banded gneiss lie by the roadside, and east of this similar blocks of a dark green rock, seemingly hornblendic, and of a gabbro. The latter rock appears to be intrusive, and is the usual Alpine gabbro; but it exhibits the common modification, the felspar passing to a kind of saussurite, the diallage to fibrous hornblende, and occasionally a foliation, due possibly to pressure.

* Microscopic examination shows this rock to have been so much modified by subsequent pressure that the original structure has been almost obliterated. So far, however, as it can be discerned, it appears that of a true granite rather than of a granitoid gneiss. The minerals are chiefly quartz, felspar, and a chloritic mineral which often occupies the cracks, and probably indicates the former presence of biotite.

† These modified dykes or masses of felstone occur not seldom in the crystalline districts of the Alps.

After this a more micaceous and banded rock is seen *in situ*. West of Livet comes a fairly strong mica-schist containing many tiny garnets, and traversed by numerous quartz-veins (Appendix, p. 101). In it cleavage-foliation has been developed at an angle of about 70° with the horizon, without, however, materially interfering with the cohesion of the mass. It is later in date than these veins, for they have been bent into serpentine curves, which are thickened at the crests of folds and attenuated at the sides, just like bands of sand in clay under pressure, illustrating in a very interesting way the principle of solution and deposition indicated by Dr. Sorby.

Beyond this place the crags recede from the road as the Combe de Gavet opens out; but the great infold of Jurassic rock, out of which has been excavated the singular plain around the confluence of the Olle and the Vénéon with the Romanche, affords a wonderful spectacle. The strata here are very distinctly bedded, not unlike parts of the Lower Lias of England, and thus, by structure as well as tint, are distinguished at a glance from the underlying crystalline masses. Cleavage is well defined and is not far from the vertical; it cuts the bedding at various, but generally high, angles, because that structure not unfrequently is almost horizontal.

(β) *Bourg d'Oisans to Le Dauphin: Grandes-Rousses Range* (fig. 1).

Roughly to the north of Bourg d'Oisans the crystalline rock reappears from beneath the stratified. On the south side of the valley the former rises sharply up from beneath the latter to form a peak, perhaps 8000 feet above the sea; on the north side an "epaulette" of the latter rests on a kind of shoulder of the former, so that the peaks of the Grandes Rousses are almost enclosed by the Mesozoic rocks. North of the town a small mountain-road gives a good opportunity of studying the relations of the two series, for it zigzags over their junction, which, however, is only perfectly exposed in one or two places.

The crystalline rock is a rather fine-grained and somewhat massive gneiss, exhibiting distinct light and dark bands, which are often about $\frac{1}{3}$ inch thick. It is not fissile, for it breaks readily across this structure, which has a strike between N.N.W. and N.W., and a dip of from 75° to 80° on the eastern side. Microscopic examination (Appendix, p. 101) indicates that the rock, after crystallization, has been modified by presssure; but I am very doubtful whether the banded structure can be attributed to this, and think that the rock when thus affected must have been already a banded gneiss resembling those of the Laurentian series. The base of the Jurassic series is a hard quartzose grit, which has apparently derived its materials from the underlying rock. Here and there it becomes conglomeratic, the fragments seeming to be identical with the underlying gneiss.

About two miles from Bourg d'Oisans the Romanche issues from a narrow gorge; the valley of the Vénéon, which drains the interior of the great horseshoe of high peaks forming the *massif* of the High

Alps of Dauphiné, being the more open of the two valleys. So far as we could see, the wall of cliffs on the north side of the former river consists of gneiss similar to that described above, except that as we approached the entrance of the gorge the rocks became slightly greener in colour, and blocks of a greenish chloritic rock (possibly a modified diabase) occurred occasionally among the screes. But close to the entrance is a fine crag of a granitoid rock *, and about a furlong further, on the left bank of the Romanche (the road having crossed the river), we find a little of a similar rock, apparently intrusive in a greenish banded gneiss, like that on the opposite bank. The structure of this rock strikes a little W. of N.W., dipping at about 45° on the N.E. side.

The road now ascends on the left bank of the Romanche (which dashes along at the bottom of a gorge), passing over banded gneiss varying from coarse to fine, occasionally distinctly micaceous, and more usually resembling the green variety mentioned above. The strike of the structure continues practically unchanged; the dip varies, ranging commonly from about 35° to 60°. The rock sometimes assumes a "slabby" structure, with the surfaces parallel to the mineral bands. The rock has, no doubt, been modified by pressure, though to what extent, in the present stage of our knowledge, can hardly be determined; but it produced on my mind the impression that we had before us a very ancient type of rock, which, anterior to the last modification, was gneissoid rather than granitoid. After a time the dip steepens till it is almost vertical, and then the rock becomes greener and more chloritic. Then, about 7 kil. from Bourg d'Oisans, a cultivated slope of *débris* conceals the section for some distance; after this the road traverses a rather fissile gneiss, striking rather E. of N., and dipping eastwards at 60° at least. To this succeeds a grey granitoid rock, with "sheen" surfaces, which dip roughly E. at about 45°; then comes, after another interruption, a very fissile rock, with a similar strike, reminding me of a common "crush type" in the Alps (*e. g.* one on the St. Gothard, just above Amsteg). Beyond this we come upon a sharp infold of Carboniferous rock. This narrow trough, well shown on Prof. Lory's map, runs almost due north for about 10 miles from near Vénosc, in the Vénéon valley, to the west flank of the Grandes-Rousses peaks.

This Palæozoic rock is a carbonaceous † slaty rock, containing small fragmental scales of silvery mica (Appendix, p. 102). It is not more metamorphosed than any ordinary slate, and can be readily distinguished by both colour and texture from the crushed crystalline series, though, as the latter is at last almost pulverized, and a

* Microscopic examination shows the rock to consist of quartz, orthoclase, a very little microcline, plagioclase, some more or less altered biotite, with a few small zircons and other microlithic minerals. It has evidently undergone considerable crushing, followed by cementation, but it retains in part the characteristic structure of a true granite. It is a variety of the "protogine" of the region, and a very similar rock forms the two highest peaks of the Grandes Rousses.

† A little anthracite is worked among the mountains near the north end of the trough.

band of arkose may possibly exist at the base of the former, it is difficult in the field to put one's finger on the actual junction. But this neutral zone is at most only a very few feet in extent, and is no proof of transitional metamorphism, for it is merely a local accident, where Dame Nature has "smudged" her handwriting. Only a few dozen yards of the Carboniferous rock are exposed, then comes some more *débris*, after which the crushed crystalline rock reappears. In both the cleavage maintains the same general direction, and is obviously due to one (Post-Carboniferous) set of movements.

As we approach the village of Freney the crystalline rock gradually becomes less fissile and more granitoid in character. Just beyond Freney is the second infold of the Carboniferous group. A small quarry has been opened in a slabby rock, with sheen surfaces dipping roughly 60° E. This, at the time, I was disposed to refer to the old crystalline series; but microscopic examination makes its true nature rather doubtful, and it may be a modified igneous rock of later age. This, however, is not very material. On the further side of the quarry is indubitable Carboniferous rock. First is a rather micaceous quartzose grit, then a black slaty rock, like that already mentioned, in which presently bands of conglomerate or breccia and of arkose are intercalated (Appendix, p. 102).

The eastern side of the trough exhibits indications of an overthrust. The end of the Carboniferous infold is like a V with the apex pointing eastward and one limb nearly horizontal. Between the latter and the subjacent crystalline series is a quartz vein, the upper surface of which has a marked slickensided structure, the striæ running eastwards. The effects of pressure are markedly indicated even in the coarsest bands of the infolded rock. The fragments in the breccia are mostly either a grey granitoid rock or a greyish banded gneiss, the latter exhibiting "sheen surfaces" parallel with the bands. These surfaces, however, bear no relation to the cleavage of the matrix, for they point in all directions. Sometimes in two adjacent fragments they lie almost at right angles, and in one instance I noticed three adjacent fragments in which the surfaces were rudely parallel to the faces of a rhombohedron. Hence they must be a record of Pre-Carboniferous earth-movements *.

The crystalline rocks east of this infold may be described as greenish schist, very probably granitoid or gneissoid rock modified by crushing; but nothing noteworthy occurred before we reached the infold of Jurassic rock near Le Dauphin, which comes down below the level of the Romanche. In the schist, which is much veined with quartz, the foliation (cleavage) strikes between N. and N.N.E., and dips at about 45° on the east side. In the Jurassic rock, commonly a dark slate, cleavage appears to be coincident with bedding; the trough extends southwards for full eight miles, crossing the Vénéon valley at Vénosc, a village which can be reached from Le Dauphin by a low pass, where the grassy alps, due to the

* My studies of the Carboniferous conglomerate at Vernayaz have led me to a similar conclusion.

presence of the slate, contrast curiously with the rugged crystalline crags on either side.

(γ) *Le Dauphin to Briançon by the Col du Lautaret.*

The crystalline series reappears on the right bank of the Romanche, 65 kil. from Grenoble (10 miles from Bourg d'Oisans), as a grey, rather coarse, foliated gneiss, like some of that in the Central Alps. The foliation in several places exhibits distinct folds; the rock here and there approximates, but not markedly, to an "*Augen-gneiss*" in structure. About one kilometre further it becomes more micaceous and more definitely banded. Next, at about the same distance further on, we come to huge fallen blocks of a hornblende-schist, sometimes well banded, and of a gabbro, which, as it includes distinct fragments of the hornblende-schist, must have been intruded after that rock had attained to its present condition. Beyond this place the scenery of the Combe de Malaval becomes yet wilder, but, unfortunately, the cliffs are generally separated from the road (right bank) by great slopes of screes. The blocks, however, so far as I could see, are a greyish, moderately banded gneiss, very like that which occurs *in situ* lower down the valley, so that I have no doubt as to the general nature of the section.

About 3 miles below La Grave an outcrop of a similar rock occurs by the roadside (Appendix, p. 102). In short, the *massif*, cut by this part of the Romanche, appears to me mainly to consist of a rock which, though modified by subsequent pressure, was originally a moderately banded, not very coarse gneiss, of a decidedly Laurentian type, such as I have seen, in other parts of the Alps, apparently underlying the gneiss of the Lepontine type, and not unlike some in the Central Oberland or that near the Trient gorge.

Before we reached the little village of La Grave, the dark Jurassic rock which, though generally out of sight, is supported by the cliffs overhanging the Combe de Malaval, and forms the range between the valleys of the Romanche and the Arc, sweeps down to the bed of the river, and the Lautaret road finally quits the crystalline rock. But on the opposite side of the valley, peaks and ridges of the latter rock tower on high. We are on ground made classic by the labours of Elie de Beaumont, Lory, and others; but as, even now, it is rarely visited by our countrymen, I shall venture on a very brief description. As already stated, the principal peaks of the central *massif* of the Dauphiné Alps are roughly grouped in a horseshoe curve. Its interior is drained by the Vénéon, a river fed by many glens, commonly steep, and leading up to glaciers. On the north the *massif* is sharply defined by the narrow valley of the Romanche; on the south, less perfectly, by the Val Godemar, but the crystalline district extends for some distance further in this direction.

Some short but very lofty spurs project towards the east from the crest of the watershed, the longest and northernmost being sometimes called inclusively the Crête du Glacier Blanc. The Pelvoux, one of the best-known summits of Dauphiné, though not quite the

highest, terminates a shorter spur to the south. Several of the peaks rise above 12,000 feet, the highest, Les Écrins, attaining 13,462, while the passes between them generally range from 10,000 to over 11,000 in elevation. Opposite to La Grave the northern face of the *massif* rises with unusual steepness. From the door of the hotel we look up to the jagged *crête* of the Meije, the highest point of which is 13,081 feet above the sea. According to the French map, the distance between the summit of this peak and the bed of the Romanche, which is considerably, perhaps 200 feet, below La Grave, is about 4500 mètres, and the difference of elevation is hardly less than 2500 mètres, giving an average rise of 5 in 9, or more than 1 in 2. The impression produced on the mind is that a great dome-like mass of crystalline rock has been pushed through the sedimentaries, thrusting them back, crumpling them about its edges, infolding portions in its undulations, or lifting them upon its arches. The great folds in the Jurassic strata at the base of the Meije opposite La Grave—which may be seen in every photograph—are well known to many. This mass of slate can still be traced some distance up the glen, which descends from the Glacier de la Brèche de la Meije; and I detected last year two small outliers at the foot of the glacier, one on either side, at a height probably of about 8000 feet above the sea. Perhaps even more remarkable is another outlier further to the west, where a long spur running in that direction from the Râteau (the mountain west of the Brèche), falls down rather abruptly to a huge glacier-covered plateau. Here we find a little outlier of black Jurassic slate, at the Col de la Lauze, 11,500 feet above the sea*. I do not know the exact height of the base of the Jurassic series across the Combe de Malaval due north of this point, but it can hardly exceed 6000 feet, so that we have an uplift of about 5500 ft., or not less than a mile vertical in about 3 miles †.

At La Grave we spent 3 or 4 days in order to acquire a general idea of the rocks forming the northern face of the crystalline *massif* by examining both the glen descending from the Brèche de la Meije and the larger valley, the main stream of the Romanche, which sweeps round the eastern flank of the Meije, and thus drains both the range for some distance south of that mountain and the north face of the Crête du Glacier Blanc. Examination of rock *in situ* and of the materials brought down by glaciers and torrents, recollection of my earlier scrambles, and study of Mr. Coolidge's collections from the higher peaks and passes, enable me to indicate with, I believe, tolerable correctness the chief varieties of rock which occur in this wild region. The rocks from the Râteau eastwards are mainly divisible into two pretty distinct groups, one consisting of rather granitoid gneisses, the other more or less gneissoid granites. In

* There is another on the glacier lower down, perhaps 10,000 feet above the sea.

† These masses may be carried up by upthrust faults; but I have seen no evidence of this, and it seems to me more like a bending of the underlying crystalline and the Jurassic in common, which has produced local crumpling of the latter.

the valley descending from the Brèche gneiss may often be seen *in situ.* This is a strong grey gneiss with a fairly well-defined banding of lighter and darker rock, the colour being due to the comparative absence or presence of a ferro-magnesian mica. The bands are often from a quarter to half an inch thick, and the rock usually breaks without difficulty across them. It closely resembles in all respects many of the Laurentian gneisses of Canada and the Hebridean (mica) gneisses of North-west Scotland (Appendix, p. 102). Probably it has been somewhat modified by pressure followed by recementation; but I cannot attribute the mineral-banding to this cause, and believe that whatever may be its true explanation, the rock prior to the deposition of the Jurassics was a banded gneiss of Laurentian aspect. Among the *débris* fragments of granitoid rock are commoner than those of the gneiss. More than one variety is present, the commonest being a moderately coarse-grained rock, often in good preservation, with a slightly pink-coloured felspar and with green spots; indeed it resembles some of the St. David's (so-called) Dimetian *. It exhibits but little sign of mechanical disturbance. The other (less common) is a coarser rock, occasionally slightly porphyritic, with some of its felspar of a pinkish, some of a greenish hue. This also appears to be a granite, though it is a little modified by pressure, which may be a record of the great upheaval.

In the glen of the Romanche the crystalline rock rises sharply from beneath the slate in the face of a steep wall, which forms a kind of step in the level. This too is a gneiss of the type already described, and among the *débris* brought down from the crags around the upper glens we find many representatives of a coarse gneissoid rock, varying from a moderately fine grey rock with but little mica, to a rather coarser rock with dark bands, which contain a considerable amount of black mica. In the latter, the bands often exhibit contortion, and though I recognize the effects of pressure, this appears to me to have affected a rock which had already acquired a banded structure. Here also the rock can commonly be broken across the mineral bands. Blocks of granitic rock are also abundant, varieties of the types already mentioned; but here the coarser and somewhat porphyritic rock is commoner than in the glen of the Meije glacier. These granitoid rocks are the typical protogine of the region: the felspar varies from a tolerably distinct red to almost colourless; the brown mica is converted more or less perfectly into a green mineral, often called chlorite, and a greenish film usually coats the joint-faces.

I also examined the slaty rocks of the Jurassic series with considerable attention, in the hopes of finding indications of incipient

* Microscopic examination shows the rock to consist of quartz, orthoclase, plagioclase (in part at least oligoclase), and some biotite, which has generally been replaced by a green mineral, with separation of black iron oxide along the cleavage-planes. There are also one or two original grains of magnetite. The rock exhibits some indications of mechanical disturbance subsequent to its first consolidation; but the structures characteristic of a rock of igneous origin are generally well retained, so that the rock is beyond doubt a true granite, perhaps rather richer in plagioclase than in orthoclase.

foliation, but with little or no success. In the immediate neighbourhood of La Grave this rock is a dark slate, so uniform in its mineral character that the direction of bedding is not easily ascertained. Indeed even in the great folds opposite La Grave the beds are more distinctly seen at a distance than when on the spot. The cleavage, of course, cuts the stratification at very different angles, being often coincident with it, though sometimes highly inclined to it. A slight satiny sheen, caused by extremely minute films of mica (sericite?), may sometimes, but by no means always, be observed, and of this the best examples were found on the Alps north-west of La Grave, some 1800 or 2000 feet above the village. Here I noticed that the mica-flakes became distinctly larger in immediate proximity to a quartz-vein, when it had also been squeezed *. Often, however, the rock is quite an ordinary slate, as in the case of a specimen taken from within two inches of a junction with the gneiss in the glen below the Meije glacier (fig. 2). Here, so far as I could judge, there

Fig. 2.—*Junction of Gneiss* (A) *with Jurassic Slate* (B) *in glen below the Meije Glacier.*

were no signs of faulting. First a little notch about an inch wide filled with soil, in which Alpine plants were growing, and then a

* We have veins of quartz and occasionally of calcite, sometimes prior, sometimes posterior to the cleavage. This effect of an included hard mass on the development of secondary mica in a rock may often be observed in disturbed regions.

quartz-vein of about the same thickness separated the black slate * and the grey gneiss (fig. 2), and I believe the two rocks have been simply doubled up together. In this glen, and at one place on the above-mentioned alps across the Romanche, I found some Belemnites curiously distorted by pressure.

The road from La Grave to the Col du Lautaret passes over dark Jurassic slates, which (about 9 kil. from La Grave) are interbanded with an impure black limestone ; the former rock is distinctly cleaved (parallel with its bedding), the latter practically uncleaved. On the descent from the pass, hard grits and quartzites occur, referred by Prof. Lory in part to the Trias, in part to the Carboniferous. At these I only glanced in passing, as there was little specially interesting in their lithological character. I need only add that a moraine near Le Casset, which represents a collection from the eastern part of the northern face of the Crête du Glacier Blanc, consists mainly of a strong gneiss, like that described as occurring on the Lautaret road below La Grave, only it is perhaps a little greener in tint.

The result, then, of our researches in this part of the section may be summed up in the following extract from my diary :—"I have nowhere seen any rock that reminds me either of the Lepontine gneiss (Montalban type), or of the Tremola schists, or of any of the group of the upper schists in the Central Alps. Everything (excluding the Carboniferous and Mesozoic rocks) appears to be either granitoid rock, probably of igneous origin, or else a strong gneiss of Laurentian type, which in the *massif* south of La Grave does not, as a rule, exhibit marked sheen surfaces, though it is often much corrugated. Some of the bands in the gneiss and some varieties of the rock itself are rather rich in mica (mostly dark), others comparatively poor. Green rocks, hornblendic or chloritic, are not common, though there is often a coating of this tint."

B. *From Briançon to Turin.*

(a) *Section of the Mont Genèvre Pass.*

The road to this pass runs for some little distance up the Clairée Valley north of Briançon, then mounts in an easterly direction up the slopes of a glen. The rock *in situ* here is a Jurassic limestone, but erratics of a gabbro, often coarse, occur occasionally,—the felspar converted into saussurite, the dark crystals of diallage sometimes partly replaced by hornblende. We also observed pieces of a dark serpentine, with crystals of bronzite or bastite, which could easily be matched from the Grisons or the Ligurian Apennines. Both these probably come from a *massif* south of the upper part of the pass.

* I have examined a specimen taken about 2 inches from the face of the gneiss. There are one or two minute constituents of minor interest, but for my present purpose it is enough to say that it is a common type of slate, with less evidence of the development of secondary minerals than I have often seen in Palæozoic slates in regions of great disturbance.

On arriving at that point we spent a considerable time in vainly endeavouring to strike the northern edge of this *massif*, though we saw the rock at a distance across a valley. Our failure was, I believe, caused by a slight misunderstanding of our map, which was on a small scale and not in much detail. Thus we missed the only place where the *massif*, as I now see, can, without much trouble, be reached from the highroad. We saw, however, some scattered fragments, which were mainly gabbro, as above described.

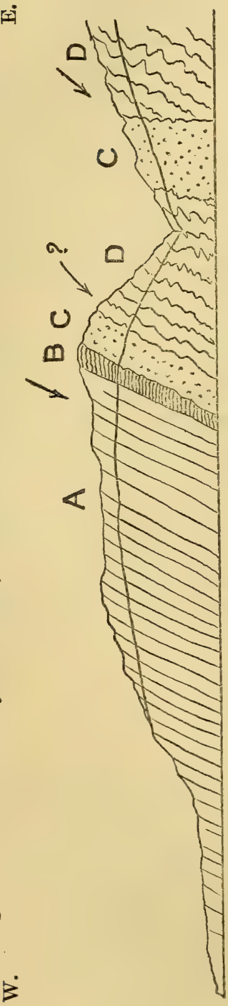


Fig. 3.—*Sketch Section from Briançon over the Mont Genèvre to the Col de Sestrières.*

A. Jurassic Rock. B. Trias? C. Serpentine. D. Crystalline Schist.

Jurassic limestone, often dark in colour, extends to the commencement of the steeper part of the descent towards Italy (fig. 3). Here it has a high dip, 75° or more to the W.N.W. Beneath a thick conspicuous mass of this rock comes a calcareous deposit of uncertain nature, not unlike a tufa *, to which succeeds a dull-green serpentine, rendered very schistose by crushing. Its rude cleavage - structure appears to be roughly parallel with the bedding of the dark limestone. To the serpentine, of which there is a rather thick mass, succeeds a lead-coloured, rather calcareous mica-schist, also intensely crushed, the resulting structure being parallel with that in the serpentine. This much resembles some members (when highly crushed) of the "*kalkhaltige grauer Schiefer*" of the Central Alps. The two rocks may be seen near together; but in the neighbourhood of the road we could not find an actual junction. Between this place and Cesanne, we saw *in situ* only varieties of this crushed mica-schist, and below the village is more of the same rock, rather darker in colour and somewhat more calcareous, its dominant structure, which dips to the S.W. at a moderate angle, being the result of subsequent pressure. (Appendix, p. 103.)

* Part of the '*Gypse et carnegules*' (Trias) of Prof. Lory's map.

(β) *Section of the Col de Sestrières.*

The road, not long after leaving Cesanne, crosses over a great mass of serpentine. On the west side of this is the usual mica-schist, which can be seen cropping out very near the serpentine, though the actual junction, at any rate about here, is masked by *débris*. But the latter appears to cut across the schist like an intrusive mass. The serpentine at first is greatly crushed, but the effects of this gradually disappear, and fairly normal specimens can be obtained. It is of the usual Alpine type, a dull greenish-black rock containing crystals of bronzite or bastite. In its peculiar joint-planes, its mode of weathering, its brown rugged surfaces, it exactly resembles the Lizard serpentine *. The rock on the eastern side of the mass becomes greatly brecciated, and is associated—apparently intrusively (but the effects of subsequent disturbance obscure the relation)—with a compact green schist (Appendix, p. 103), which now and then is reddish in colour, and reminded me much of a rock which occurs on the west side of the Julier Pass (Engadine) To this succeeds a calc-mica schist, like that below Cesanne, much disturbed and crushed, and exhibiting "sheen surfaces." Higher up another variety, which in general appearance reminded me of some of the calc-mica schists of the Central Alps (*e. g.* the mass north of Olivone), proved that a cleavage-foliation had been superinduced in a rock already foliated, for in places the former structure clearly cut across the contortions of the latter (fig. 4). Calc-mica-schists of one general character (Appendix, p. 103), but with minor variations, as when, for example, the rock reverts to the anthracitic type near Champlain du Col, continue till the trough on the upper part of the pass is reached. The "stratification-foliation" strikes generally between N.N.W. and N.W., dipping at about 45° on the average to the western side.

In the first part of the descent from the Col very little rock crops out near the road, and as far as Pragelas we saw nothing but schists of the above-mentioned type; sometimes one of the more anthracitic varieties, like that below Cesanne, sometimes one of the more micaceous, like that on the east side of the Mont Genèvre, sometimes one rather more massive, which recalled to mind the "brown-bedded" rock of Olivone †. There is nothing needing special remark between Pragelas and Fenestrelle, near to which mica-schists occur, dipping apparently at about 50° rather to the S. of W.‡ At the

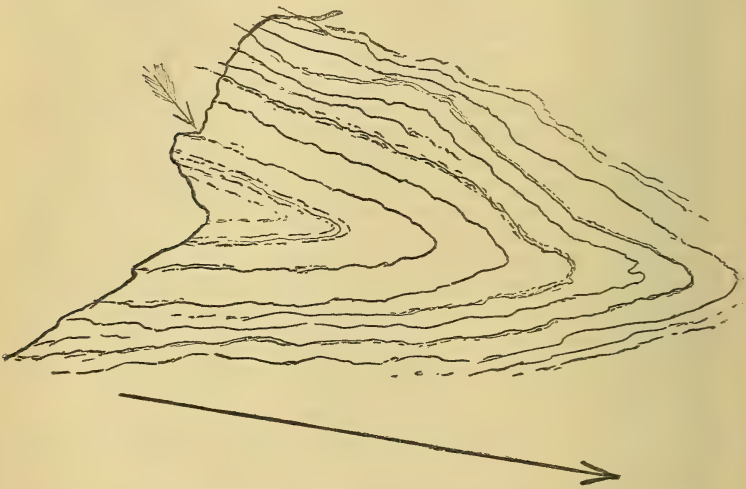
* It is needless to give a description of the microscopic structure; it is a perfectly typical serpentine, such as the dark serpentine from the north of Cadgwith, the similar rocks from near Genoa, near Figline, and the Engadine—a serpentine, varieties of which occur here and there throughout the Alps. This one is an altered olivine-enstatite-augite rock (*Buchnerite* of Wadsworth), the first and second minerals being completely serpentinized.

† Quart. Journ. Geol. Soc. 1886, Presid. Address, p. 47.

‡ These differ greatly from the schists described above. Under the microscope their structure is coarser, "cleaner," and more like that of schists at a lower horizon, *e. g.* a silvery mica-schist which I have found in various localities in the Lepontine and Noric Alps. The specimen examined consists of quartz and white mica with some kyanite.

base of the hill, crowned by the celebrated forts, is a felspar-actinolite rock *, possibly of igneous origin, followed by mica-schist, and a dull green rock banded with epidote, dipping much as before. The rock in this neighbourhood is stronger and less easily weathered than that higher up the valley, and recalled to my mind some of

Fig. 4.—*Diagram of "stratification-foliation" in Calc-mica-schist near Col de Sestrières.*



The lines roughly indicate micaceous layers; the long arrow is parallel with the "cleavage-foliation" of the mass; the small arrow shows the place where a specimen was taken for examination (p. 103).

the chloritic and micaceous rocks about Zermatt or near St. Vincent in the Val d'Aoste †. Below Fenestrelle this change in character becomes yet more marked. The rocks now are more massive, forming bolder crags which are no longer masked by a talus of shivery schist; in short, the same change in the scenery may be observed

* Consists chiefly of epidote, actinolitic hornblende, quartz, felspar and hæmatite, with some sphene and rutile. The microscopic structure is interesting in many ways, but it is enough for my present purpose to say that subsequent mineral rearrangement has made it difficult to be sure of the original condition of the rock, but I think that it probably was igneous, and that pressure has not been the sole agent of change.

† Minerals: quartz, epidote, mica, white and brown, chlorite (probably in part, at least, replacing the latter), garnet (red), a little rutile and a colourless doubly refracting mineral of ill-defined limit and form, probably allied to zoisite or epidote. The rock is distinctly foliated and banded. The constituents, especially the white mica, are fair-sized and well defined, as if freely formed; so if the foliation results from pressure, a good deal of mineral change has subsequently occurred. The structure is, for a schist, a little abnormal; possibly that may be connected with the presence of a neighbouring intrusive mass.

when, in other parts of the Alps, we are quitting the "Upper Schists" and entering the stronger more coarsely crystalline series which often underlies them. Unfortunately we had no opportunity of examining the rock (which we deemed to be a mica-schist) *in situ* till we reached La Balme, where we found a schist with bands of mica (in rather large flakes) and a fine-grained gneissoid rock, the association of the two being suggestive of some kind of stratification of the original constituents. The rock resembled one in the Lepontine series near Altanca *. The dip was about 30° to N. 10° W. Yet lower down comes a strong brownish mica-schist, with little, if any, mineral banding and no strongly marked foliation, which has nearly the same strike, but is almost vertical, dipping perhaps slightly on the northern side †. This rock continues with little variation for a considerable distance; but about a mile before reaching La Perouse, a quarry has been opened in a paler-coloured gneiss. The brownish mica-schist, however, occurs again below the town. After an interval without any outcrops near the road, we find just below San Germano a gneissoid rock, not impossibly of igneous origin, dipping (if the faint indications of structure can be trusted) approximately at 45° to S.E. It becomes slightly more gneissoid and is succeeded in about a furlong by a finer-grained rock of brownish colour inclining sometimes to greenish grey. This exhibits a moderately definite foliation, but includes masses of a darker colour; these may be nodes, but certainly in some cases they look like fragments of a crystalline rock. The dip of the foliation (there is no mineral banding) is roughly to S. at about 50°. Another quarry still lower down gives a rather more definite dip (45° to E.S.E.). Below this the valley opens out as we approach Pinerolo and reach the margin of the plain of Piedmont.

II. The Eastern Alps from Lienz to Kitzbühel.

(*a*) *Nomenclature of Rocks.*

According to Von Hauer's map of the Eastern Alps, which, though on a small scale, we found an excellent piece of petrographical work, the fundamental rock is a group of gneisses, called the Central Gneiss; to this succeeds ordinary gneiss, and to this mica-schist. Last of all comes a formation called by him "*Thonschiefer.*" Hornblendic and chloritic schists and crystalline limestone occur rather locally at horizons the position of which will be described further on. North of the central range is a band of greywacké and slate, which is referred to the Silurian, and can be traced for many miles. The northern and the southern range consist mainly of sedimentary rocks, chiefly limestones or dolomite, which, as is well known, are of Triassic or later age. These also in all probability once extended

* Quart. Journ. Geol. Soc. 1886, Presid. Address, p. 69.

† For the microscopic structure of these and the following rocks, see Appendix, p. 103.

over the crystalline rocks of the central range, from which, however, they have been almost entirely removed by denudation. Of the igneous rocks of the region, especially those of the Southern Tyrol, it is needless to speak. The above-named "*Thonschiefer*," with the lower part of which some chloritic schists and crystalline limestones are associated, is extensively developed in the Eastern Alps. The name "*Thonschiefer*" is vague; for, if I mistake not, it might be applied to either a clay-slate or an aluminous schist. Certainly the rock is not the former, though sometimes locally, when greatly crushed, it presents a strong resemblance to it. In the extensive rock-collection of the Innsbrück Museum the series is called "*Thon-glimmer-Schiefer*," which is made less ambiguous by the inserted word. I have a difficulty in finding an English equivalent. *Clay-mica-schist* is misleading, *aluminous mica-schist* awkward; *upper mica-schist* is open to objection as involving an assumption as to stratigraphy; *phyllite* suggests too fine-grained a rock; so I propose, at present, in the poverty of English nomenclature, to retain the German term "*Thonglimmerschiefer*."

(β) *The Pusterthal and Neighbourhood.*

We travelled by railway up the valley of the Adige, traversed the igneous rocks in the neighbourhood of Bozen, and in due course reached the "*Thonglimmerschiefer*" south of Klausen *. With the members of this group previous visits to the Tyrol had already made me fairly familiar, and I could see, even as I passed by, that though they varied somewhat in texture and hardness, the dominant rock is a moderately soft, dull lead-coloured mica-schist, in which the individual films are not conspicuous to the eye, at any rate at the first glance. This obscuration of the true structure is very probably the result of crushing. The apparent foliation is a cleavage-foliation the conspicuous surfaces are "sheen surfaces," which exhibit a peculiar gloss, looking sometimes like the polished black-lead of a fire-grate.

These macroscopic characteristics are very commonly so general and so uniform, that one can recognize the rock with certainty even from a railway-train †. Our first halt was made at Brunecken, where the "*Thonglimmerschiefer*" series is well exposed close to the town, and presents some interesting variations. The picturesque old castle stands on a craggy mound of white crystalline limestone (Appendix, p. 107); this, on the southern side, is distinctly "bedded" like an ordinary limestone, and dark streaks occur in the rock parallel with this structure. The beds are much twisted about, but they appear to have a general strike about S.S.E., with a high dip.

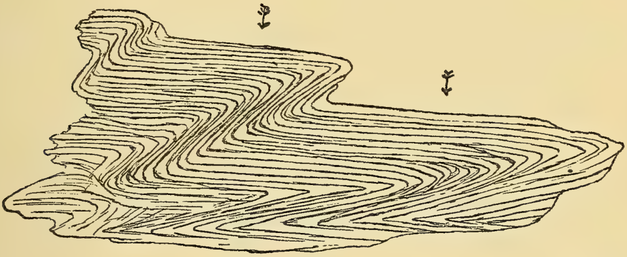
On the northern side a little mica-schist crops out, apparently *in situ*; but its strike is nearer E.S.E. Then comes (after a short

* In several places, as I have myself seen and have learnt from the Innsbrück Museum, the dolomites of the Italian Tyrol rest on either "*Thonglimmer-schiefer*" or mica-schist.

† I have verified this assertion many times.

interval), apparently in due succession, a fissile greenish or lead-coloured mica-schist, its dominant structure being a cleavage-foliation which strikes roughly S. of W. and dips at about 75° on the eastern side. A quarry on the hill-side about 80 feet above this gives a more definite strike W.N.W. to E.S.E., with a high dip on the southern side. Here the rock distinctly exhibits a stratification-foliation and a (subsequent) cleavage-foliation, the former being indicated by quartzose layers from about ·1″ to ·2″ thick, separated by thin but well-defined layers of mica. The two structures commonly coincide; but instances may be found where the mineral bands are bent, folded, and zigzag across the direction of the cleavage-foliation, as the "stripe" often crosses the cleavage in a banded slate. Where the two coincide, the layers of mica are crushed and burnished, probably by a slight shearing, while in the crossing they are puckered and rather crushed, but the bands of quartz are only slightly affected (fig. 5).

Fig. 5.—*Quartz-mica-schist from Quarry near Brunecken.*



The lines indicate the thin bands of mica; the arrows point to the "sheen surfaces" at right angles to the visible face of the block. Length about 1 foot.

As the section which we proposed to make across the Central Chain promised to exhibit but little of Von Hauer's gneiss, we made a short excursion from Brunecken into the Antholzerthal. Here, above Oberrasen, we found excellent exposures of the former rock. It is a grey gneissoid granite, rather coarse and sometimes porphyritic in texture, slightly foliated, but without mineral banding. In its jointing and mode of weathering it much resembles a true granite, and somewhat reminded me, in its general aspect, of the granite on the Lukmanier Pass. South of this, perhaps mapped as mica-schist, is a gneissic rock, much more fissile, on the original character of which, owing to the great crushing, it is difficult to decide. The cleavage-foliation struck a little S. of S.W. and was nearly vertical, corresponding with the foliation in the granitoid rock.

Between Brunecken and Lienz, the railway to beyond Olang and below Innichen passes or cuts, not unfrequently, outcrops of the "*Thonglimmerschiefer*," which is generally of the normal lead-coloured variety. On this rock evidently rest the great masses of dolomite

which rise just south of the line for some distance on either side of the Toblacher plateau. This is the singular, flat, drift-covered watershed between streams which drain on the west to the Adriatic, on the east to the Black Sea.

(γ) *Lienz to Mittersill.*

At Lienz we turned northward, ascending the valley of the Isel, a broad strong stream which forms an important tributary of the Drave. A short distance above the town, by the bridge over the Isel, is a knoll of "*Thonglimmerschiefer*," a somewhat banded, lead-coloured schist, tolerably hard and strong, the structure dipping at a low angle to the E.N.E. This, as I wrote in my diary, "is a rock similar in general character to that which we have been seeing ever since we came near Klausen" (Appendix, p. 106). Between two and three miles from Lienz we came to a number of outcrops of a very different type of rock. This resembles one of the strong but rather micaceous schists, or fine granular gneisses containing much black mica, that are not rare in the Alps. It is the "mica-schist" of Von Hauer; his "gneiss," of which only a comparatively narrow band is exposed, recalled to me the granitoid rock of the Antholzerthal. It is succeeded by more "mica-schist." Near St. Johann im Wald is a second small outcrop of "gneiss." Blocks fallen from the crags above indicated two types of rock, one a fine-grained gneiss, the other a coarse-grained rock with crystals of tourmaline and large flakes of mica. Rain prevented us from giving much attention to this outcrop; but the general aspect of the crags and of the blocks scattered by the road reminded us of the granitoid rock in the Antholzerthal. Beyond St. Johann the "mica-schist" recurs, and we examined it more than once. The rock is often very distinctly banded with alternating white (quartzose) and dark (micaceous) layers. This stratification-foliation is modified by a cleavage-foliation, which has a general W.S.W. strike, and dips at about 60° on the southern side. Sometimes the two structures coincide, but often the latter crosses the former at high angles, and various contortions are produced. In short, just as in the "*Thonglimmerschiefer*," the mineral banding behaves as the "stripe" in a slate which has been much contorted before it set up cleavage. The "mica-schist" of Von Hauer reminded me of parts of the Lepontine group, especially such varieties as we find south of the crest of the St. Gothard, or about the Passo del Uomo, and on the ascent from Airolo to the Val Piora.

For some distance below Windisch-Matrei the valley is rather open and comparatively flat, but the little town nestles at the base of the eastern mountains. The neighbouring rock obviously belongs to the "*Thonglimmerschiefer*" series. On the hills east of the town we collected *in situ* micaceous varieties of this rock, the chloritic schists associated with it (presently to be mentioned), and a white quartz-schist. The slopes also were strewn with fragments of silvery quartz-mica-schist, containing a few red garnets, with other mica-

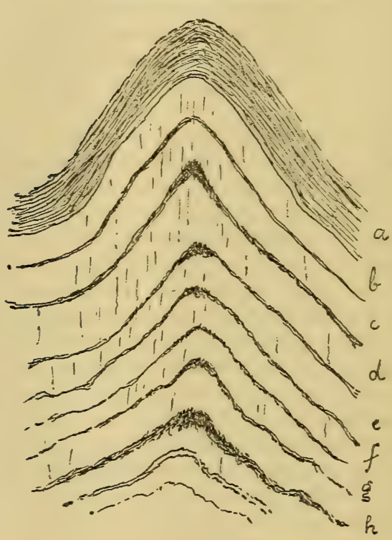
schists and fine-grained gneisses. Of these rocks, the garnet-bearing schist is exactly like a variety which occurs in the Tremola-schist group of the Central Alps; the remainder resemble the gneisses and schists met with on the west side of the Piora lake and on the upper part of the Gt. St. Bernard pass. These appeared to come from the more southern set of ravines, and recalled to mind the rocks mentioned above, with which they undoubtedly correspond. The white quartz-schist, which is very like varieties found in the Val Piora, and south of the Gt. St. Bernard, occurs *in situ* near the top of the pass leading to Kals. It dips at an angle varying from 30° to 45° to S.S.W. or a little nearer S. It is apparently underlain by chloritic schist, and that by the usual mica-schist; but I suspect an inversion due to folding.

The path up the main valley, north of Windisch-Matrei, for some miles runs entirely over members of the "*Thonglimmerschiefer*" series. The château crowns a projecting mass of white marble, quartz-veined at the base, apparently dipping towards the S. On this side a calcareous mica-schist (*Kalkglimmerschiefer*, V. H.) is exposed at the base of the crags, and in the valley below is well displayed near the bridge over the river, dipping at a high angle, about 75°, to S.S.E. This rock is lithologically identical with some of the "*kalkhaltige Schiefer*" of the Central Alps. At this point the cleavage-foliation is parallel with the stratification-foliation. The path (now on the right bank of the torrent) winds up and over a great mass of this rock, which continues to dip in the same general direction, but perhaps not quite so steeply, the strike varying between E.S.E. and E. Beautiful examples of corrugation are displayed, and the independence of the cleavage- and the stratification-foliation, though in general the two are coincident in direction, is indubitable. The accompanying diagram (fig. 6, p. 88)—a fairly careful copy of a part where the cleavage-foliation is not very strongly developed and cuts across a corrugation—will serve to prove this, and will indicate how closely the stratification-foliation simulates, if it does not signify, a structure produced by some kind of sedimentation. As the path approaches the brink of the gorge of the Tauern, chloritic schist is seen to rise on the opposite bank, close to a waterfall, from beneath the calcareous schist, the change from the one rock to the other, indicated by a little ravine and a pile of screes, being rather rapid. Presently the chloritic schist appears on the right bank, the calc-schist becoming at its base harder and more calcareous, its cleavage-foliation (probably coincident with the other structure) dipping to S. at about 50°. Screes mask the actual junction; but after about 22 yards the chloritic schist, at first seemingly rather calcareous, crops out, the cleavage-foliation dipping as before. After a while the chloriric schist becomes more distinctly banded, chloritic alternating with epidotic layers, as the felspathic bands are associated with the hornblendic in several localities in the Lizard peninsula. A greenish mica-schist, intermediate in character between the two types, or oscillating from the one to the other, which succeeds, finally passes into a typical "*kalkhaltiger Schiefer*," containing a darkish mica with

occasional greener bands. This, in about 4 yards, passes back into the green schist, which is, perhaps, at first a shade more micaceous than usual, but soon becomes perfectly normal chloritic schist *.

From this description it will, I hope, be understood that the calc-mica-schists and the chloritic schists are associated in the same

Fig. 6.—*Rough Sketch of folded Calc-mica-schist above Windisch-Matrei.*



a. Band about 1¼″ thick, chiefly dark mica.
b. Light-coloured calc-mica-rock with brownish spots.
c. *Idem*, darker in colour.
d. *Idem*, more distinctly banded.
e, f, g. Like *h*, but more brown-spotted.
h. Browner, more micaceous band.

The dark divisional lines are the distinct bands of dark mica, at most ¼″ thick. The vertical lines indicate the imperfectly developed cleavage-foliation.

manner as ordinary stratified rocks, and that there is a real, though fairly rapid, passage from the one to the other, so that it seems impossible to regard the chloritic rock as the modification of a basic igneous rock, either intrusive or interbedded.

Presently another change is shown in the face of the crags; for the rock has become a highly calcareous mica-schist, almost a marble. It exhibits every indication which we should expect from a rock originally stratified, the stratification-foliation dipping at about 70° slightly to W. of S. It is exposed for about 25 paces by the path; but, as this crosses the strike obliquely, perhaps making an angle of 30°, the thickness cannot be more than 35 feet. To this, after a few yards covered with *débris*, succeeds a very micaceous variety of

* For the microscopic structure of these rocks, see Appendix, pp. 107–109.

the "*kalkhaltiger Schiefer*," full of a lead-coloured mica, and so fissile that it is almost impossible to carry away a specimen. This rock is least micaceous in its upper part *. Higher up, after crossing the stream by a bridge, another chloritic schist is found.

Further on (approaching Grüben) occurs a rather massive pinkish and greenish rock, perhaps a syenite, modified by subsequent pressure; but beyond this is a banded chloritic schist. Its strike is slightly N. of E., but its dip is on the northern side. But after passing Frossnitz, we again find well-banded calc-mica-schist with the same strike, but a southerly dip, the two foliations being coincident. Before long, however, the character of the rock changes, for the path crosses rather silvery mica-schists and quartz-mica-schists, which dip at about 50° to S.S.E., and in the *débris*, brought down by lateral ravines, silvery mica-schist with occasional garnets and gneisses of "Lepontine" type occur. Beyond a mill (? Landeggsäge) the path mounts a rocky barrier, which consists of a rather fine-grained micaceous gneiss of the latter type (Appendix, p. 105); but in a more open part of the glen, as the "Tauernhaus" is approached, characteristic "*kalkhaltiger Schiefer*" is again found, with a S.E. dip. The gneiss below seems to dip in this direction, so that the strike appears to have gradually changed from nearly W. and E. to S.W. and N.E.

In the Gschlössthal, as the glen immediately above the Tauernhaus is called, and in the range immediately north of it—the watershed of the Tyrol Alps—the Central Gneiss of Von Hauer crops out. The most casual observer cannot fail to note the contrast between the shivery and comparatively soft schists of the "*Thonglimmerschiefer*" series and the hard, strongly crystalline rocks of the latter. These we studied, not only in crossing the Velber-Tauern pass, but also during our ascent of the Gross Venediger. The minute details have no particular interest, so it may suffice to say that banded gneisses occur generally in the lower parts of the mountain; these, whether micaceous or hornblendic—and they pass sometimes almost into strong hornblende-schists—recalled to my mind certain members, but not the most coarsely crystalline, of the Hebridean of Scotland and the Laurentian of Canada, which are often distinctly modified by subsequent pressure. We also find slightly foliated, coarsely crystalline, granitoid rock with nodes or enclosures,—probably a granite subsequently modified, the upper part of the mountain chiefly consisting of the latter rock †. But in the *débris* brought down by torrents and moraines from the right bank of the Schlattenkees, that is to say, from the western part of the chain which forms the southern boundary of the Gschlössthal, there is a good deal of mica-gneiss and schist (with muscovite and biotite), recalling the rocks seen about Landeggsäge, which seem to strike towards this part of

* The association of the two rocks just described was confirmed by returning to Windisch-Matrei by the left bank of the river, though the rocks are less perfectly exposed along this path.

† It abounds on the ascent to the Prägerhütte, and I do not remember observing any rocks except these between the hut (8,700 ft.) and the summit (12,051 ft.); but the greater part of the ascent is over snow and ice.

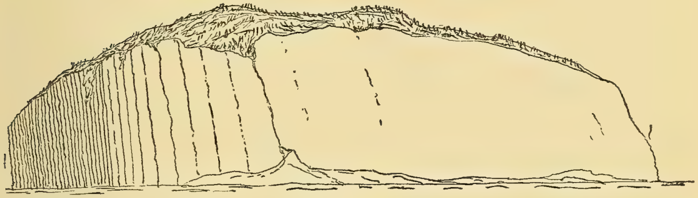
the range. These rocks have a marked resemblance to the "Lepontine gneiss" of the Central Alps. I wrote in my diary:—"The rocks seen at the head of the Gschlössthal vary in aspect from the 'Antigorio' gneiss through the Monte Leone gneiss to that of the pass of St. Gothard, but I have seen nothing which resembles the Tremola schists."

The strong-banded, micaceous and hornblendic gneisses mentioned above are traversed on the ascent to the Velber-Tauern pass. My observations of the foliation, which is often associated with mineral banding, give strikes varying from E.N.E. to E.S.E., with a moderate dip, say about 25°, on the southern side; but there are frequent indications of rolling and twisting, for higher up the dips vary from the southern to the northern side, and north-westerly strikes seem to predominate. As we approach the crest of the pass the beds are more coarsely crystalline and may be true granites; they show a certain foliation, but not mineral banding. On the upper part of the descent towards the north we meet with a considerable amount of hornblendic rock (*Hornblendeschiefer*, V. H.), sometimes dark, sometimes spotted with white felspar (?), occasionally rather coarse, slightly foliated or now and then even banded, varying from massive to rather platy in structure, on the whole very like some of the hornblende-rock in the Hebridean series. Very much, if not all, may be modified igneous rock, which hypothesis is confirmed by the outlines of the outcrops indicated on the map. Some distance from the top of the pass we noticed that, in the crags on the left bank of the upland glen which we were descending, masses of rock, probably from 50 feet to about 300 feet thick, exhibited a kind of stratification, indicated by differences of tint, and these dipped clearly northwards, at perhaps an average angle of 40°. Beyond this the bed of the glen is interrupted by a range of cliffs. The bottom of the slope is reached by a rapid and rough descent in a north-westerly direction, during which we observed that the mica now and then became more silvery, and the rock, as a whole, assumed a less "ancient" aspect. On reaching the bottom the scenery changes, the stream becoming bordered by sloping pastures and copses, and no rock was seen *in situ* till after passing the Pinzgauer Tauernhaus (3,530 feet), when a rather fissile chloritic schist crops out. Hence to near Mittersill little rock is seen, what there is being either the normal chloritic schist or green rock of a not very definite character. The lateral torrents, however, bring down blocks of fine-grained rather banded gneisses, darker and lighter, of various gneisses and schists approaching the Lepontine type, with some which appear to belong to the "*Thonglimmerschiefer*" series; but shortly before reaching Mittersill we traverse in a shallow gorge a considerable mass of chloritic schist, with a high dip towards the north (Appendix, p. 108). It is somewhat calcareous, and corresponds with the green schists in the glen north of Windisch-Matrei. According to Von Hauer's map the associated group of calcareous, micaceous, and chloritic schists extends continuously round the eastern edge of the Central-Gneiss *massif*, passing from Windisch-Matrei, by the head of the Mollthal, to the valley of the Salza, in which, among level water-meadows, Mittersill is situated.

(δ) *Mittersill to Kitzbühel.*

From Mittersill a good carriage-road ascends the mountain-slopes forming the north bank of the Salza, passing a picturesque castle, which is perched on a prominent knoll. By its side excellent sections are exposed in artificial scarps. The first rock seen is lead-coloured "*Thonglimmerschiefer*," exactly like that of the Pusterthal district, but with a cleavage-foliation so strongly marked that it masks every other structure, and generally renders the rock so fissile that it is almost impossible to obtain specimens. The structure dips at a high angle (about 70°) north, or a little east of north. Bedding, however, is occasionally suggested by changes in the tint of masses. But presently, as the road sweeps round a little knoll below the castle, a small quarry exhibits a more interesting section (fig. 7). At the lower

Fig. 7.—*Quarry below Castle near Mittersill.*
(Total length of section about 24 yards.)



A. Fissile *Thonglimmerscheifer*. B. Calc-mica-schist. C. Marble.

end it is limited by a very fissile "*Thonglimmerschiefer*." This passes rather rapidly into calc-mica-schist, and this, again, similarly changes into a banded crystalline limestone, which soon becomes quite massive, and so continues for the remainder of the exposure, except that there are some very dubious indications of bedding at the upper end of the quarry. The strike of the cleavage-foliation at the lower part of the quarry is a little N. of W., with a high dip on the northern side. This structure is generally coincident with the stratification-foliation and with the apparent bedding exhibited by the neighbouring calcareous rock, but the dip appears to become less steep towards the upper end of the quarry. This marble forms the ridge on which the castle stands, and the road, which mounts gradually in a westerly direction, leaves it on the southern side and crosses varieties of the "*Thonglimmerschiefer*," one being a quartzose schist, like that in the quarry near Brunecken. Fine sections are exposed in a lateral ravine some distance further to the west, and higher up the slope, masses of marble or calc-mica-schist (the rock varies from the one to the other) being distinctly interstratified with the typical "*Thonglimmerschiefer*." Here, in places, the cleavage-foliation is seen to cut the stratification-foliation at various angles. In the "*Thonglimmerschiefer*" are harder (? quartzose) bands, which sometimes are

almost uncleaved, while the micaceous, lead-coloured schist is almost as fissile as a slate.

Beyond this glen, the road turns away from the Salza valley, and mounts in a northerly direction to the Pass Thurn (4180 feet). Two types of rocks are exposed at intervals, one a "*Thonglimmerschiefer*," the other, and rarer, a more massive rock, schistose in aspect, apparently a kersantite modified by pressure. The former rock is at times so completely crushed that in the field it is difficult to decide whether it is phyllite or crushed schist. Sometimes it might well have been referred to the former, but now and then harder bands had the characteristics of true schists. The fissile papery varieties are unfitted for microscopic examination, but one of the latter (Appendix, p. 106) is a true schist. Hence I conclude that Von Hauer is probably quite right in mapping all on the south side of the pass as "*Thonglimmerschiefer*," but that the rock has been in places almost pulverized. The well-known sections south of Torcross in Devon were constantly recalled to my mind, but in this locality the evidence at first sight seemed even more favourable to the idea of a transition from true schist to a satiny slate. I much regretted that circumstances prevented me from making a prolonged halt at the top of the pass, and following up the rocks for some distance east and west. Still I feel convinced that the mapping is correct, and that here, as is commonly the case, the most marked effects of pressure have been produced in the upper part of the more crystalline rock. Schist, with a cleavage-foliation dipping, where measured, between N. and N.N.E., occurs on the first part of the descent, but lower down it becomes more like a normal schist and rather greener in colour. After this the valley opens out, and the road descends to Kitzbühel through rich pastoral scenery, beneath which the Greywacké (Silurian) of Von Hauer is concealed. Sections, however, of the latter can be examined in and near Kitzbühel. I have studied microscopically a specimen obtained near a mine (gold?) south of the town. The rock, though it has undergone considerable pressure, and might be called a phyllite, is quite different from any member of the "*Thonglimmerschiefer*" group. In short, this group does not appear more metamorphosed than one of the older Palæozoic series of Britain in a region where the rocks have been much compressed. It is succeeded unconformably by cream-coloured Mesozoic limestones.

(ε) *The Zillerthal and the Brenner.*

These sections cut deep into the northern side of the central chain, and enabled us to add to the evidence obtained in our traverse. According to Von Hauer, a narrow band of Greywacké, a prolongation of that mentioned above, intervenes between the base of the Jurassic series and the "*Thonglimmerschiefer*." This we were unfortunately prevented from examining *in situ*, though we saw it in fragments. "*Thonglimmerschiefer*" of a perfectly normal character is seen abundantly, first in fragments brought down by lateral torrents,

then (about $3\frac{1}{2}$ miles below Zell) *in situ*, a cleavage-foliation being the dominant structure. Similar rock occurs a little way above Zell, where it is evidently greatly affected by pressure. In the upper part of the valley around and above Maierhof, crystalline limestone, rather compacter in structure and greyer in colour than that south of the central watershed, is well developed, as, for instance, at the Calvarienberg below the village, and about a mile and a half above it, where the mass crosses the valley, and extends, according to Von Hauer, far away eastwards and westwards. Its passage into calc-mica-schist and then into normal lead-coloured "*Thonglimmerschiefer*" is excellently seen in a knoll on the left bank of the valley, where the last two, like that already described, exhibit a distinct stratification-foliation *. The crystalline limestone often has a platy structure, which strikes not far from E. and W., varying a few points on either side. In one place, above Haus, we see it almost in contact with a coarse gneiss in which a cleavage-foliation is very strongly marked, and of which the last outcrop is only about 10 feet from the last knoll of limestone. The cleavage-structures in the two rocks are not quite parallel, that in the gneiss being slightly S. of W., that in the limestone a little N. of it. At this point, we have either a granite intrusive in the limestone and crushed up with it, or a natural junction of an older and a newer series similarly crushed, or a faulted junction of the two rocks. As the limestone here is exactly in the same crystalline condition as it is in the three other localities where I examined it, I regard the first hypothesis as inadmissible. As regards the third, I saw nothing to suggest exceptional sliding and shearing, but only direct crushing. Hence I do not think there has been an overthrust-fault, and so consider it on the whole more probable that limestone and other members of the "*Thonglimmerschiefer*" series were deposited upon an old surface of the gneiss. It is true there is no sign of a basal conglomerate, but this is not without precedent.

Above Maierhof three mountain-glens pierce deep into the central chain of the Tyrol, giving the traveller another opportunity of examining the "Central Gneiss" of Von Hauer. We walked several miles up two of these, the Stillupthal and the Floitenthal, scrutinizing the rocks *in situ*, the screes brought down by lateral torrents, and the erratics on the floor of the glen. In the Stillupthal we noted a porphyritic gneiss, with occasional darker bands of lenticular outline, also sundry gneisses and mica-schists, both light and dark, which bore some resemblance to gneisses of the Lepontine type. The first-named rocks are probably of igneous origin, the difference in appearance being due to differences in the effects of crushing. Some blocks also exhibited junctions which suggested an intrusion of the porphyritic rock into the "Lepontine" gneiss, anterior to the crushing, and the foldings in certain of the schists and gneisses are such as would be most naturally explained by supposing that a stratification-foliation existed when the cleavage-foliation was pro-

* For the microscopic structure of the rocks of this district, see Appendix, pp. 106–108.

duced. If the porphyritic rock be igneous, the gneisses and mica-schists in this glen are, as a rule, of a rather less ancient type than those in the Gschlössthal and on the Velber-Tauern pass, and resemble those which occur on the south side of the former. Porphyritic gneissoid rock, similar to the above-mentioned, occasionally associated with a fine-grained gneiss—as if the one were intrusive in the other prior to the final pressure—occurs in the Zemmthal as far as Ginsling, and in the lower part of the Floitenthal, and was the chief rock seen by us *in situ*; but below that hamlet in the one, and above the "Klamm" in the other, lateral torrents bring down gneisses and schists of Lepontine type, similar to those just mentioned. Thus it seems that on both sides of the watershed the Central Gneiss becomes less strong and massive as we proceed outward, and is otherwise modified; in short, it changes from a Laurentian towards a Montalban type, without, however, quite attaining to the latter.

We made a short expedition from Innsbrück up the north side of the Brenner pass in order to examine the "*Thonglimmerschiefer*" and the *mica-schist*. The former rock, which we saw in many places from the railway and examined *in situ* above Steinach, is the usual lead-coloured schist, generally greatly crushed (Appendix, p. 106), but in which occasionally the two foliations may be distinguished. The mica-schist was examined in a quarry near Matrei. It is a fairly well-banded rock, the cleavage-foliation apparently coinciding generally with the stratification-foliation and both dipping roughly S.W. at about 25°, an unusually low angle. In it occur lenticular masses, sometimes from 1 foot to 2 feet thick, which we considered to be an intrusive granite modified by subsequent pressure. On the right bank of the valley, according to Von Hauer, is an outlier of Triassic rock, in which are two rounded patches of serpentine. One of the latter we examined carefully in a large quarry. It was tremendously crushed and veined with calcite. Here also schist is seen, apparently overlain by the serpentine. The last great crushing and the subsequent mineral changes make the relations of these rocks extremely puzzling, but I believe the following to be the most probable account. The serpentine was probably intrusive in the schist, the former rock was subjected to pressure, and the fissures afterwards were filled with calcite (perhaps obtained from overlying limestones)*. Then all the rocks were folded together and rendered fissile by crushing. The resulting structure has the usual S.W. strike. According to Von Hauer's map the serpentine appears to be also intrusive in the Trias; but on this point the sections which we saw unfortunately threw no light.

We left the Tyrol by the railway over the Vorarlberg pass, and so skirted or traversed for some distance the "*Thonglimmerschiefer*" series, which occurs mainly on the right bank of the Inn, the Triassic limestones rising in grand cliffs on the opposite side. The former rock is the usual lead-coloured schist, exactly like that so often

* *Cf.* "The history of the brecciated serpentine in the hills above Bonasola (Apennines)," Geol. Mag. dec. ii. vol. vi. p. 362.

described, but the tunnel at the eastern entrance seems to be made in a rather harder schist or in gneiss.

We were thus able to trace this peculiar lead-coloured schist—the typical "*Thonglimmerschiefer*"—in accordance with Von Hauer's mapping, along its strike, roughly speaking, for a distance of over 60 miles south of the central range, and for a distance of over 90 miles north of it, and to find it associated with similar chloritic schists, quartzose schists, calc-schists and crystalline limestones in several localities. On both sides of the central range we found gneisses and mica-schists of like lithological character, and in the heart of it, apparently underlying the "*Thonglimmerschiefer*" series, a group of gneisses, of hornblendic and granitoid rocks of more ancient aspect, which not seldom recalled the oldest rocks with which we are acqnainted.

III. Conclusions.

From the investigations above described, aided by a study of the collection in the Innsbrück Museum, I do not see how to escape the following conclusions:—

(1) The "*Thonglimmerschiefer*" series, consisting of lead-coloured micaceous schists, with more or less quartzose and calcareous varieties, sometimes becoming marbles and occasionally chloritic schists, forms a group of rocks, well defined lithologically and stratigraphically. I have traced it myself, as mentioned above; but according to Von Hauer's map (and his types are so well-marked that I feel confidence in its accuracy) this group extends eastwards to within a few leagues of Gratz, over full 5 degrees of longitude in all.

(2) Apparently underlying this comes another group, consisting of mica-schists and gneisses, bearing a general resemblance to the "Lepontine" group which is so well exhibited on the St.-Gothard Pass and in the adjacent parts of North Italy. While it is difficult in some districts to separate this lithological group from the former, the typical members of each are perfectly distinct.

(3) Yet lower, and more rarely exposed, comes a group chiefly consisting of banded gneisses, and granitoid gneisses or gneissoid granites. The latter may be igneous in origin, but they have a curiously ancient *facies*, while the banded gneisses are very like some of the Laurentian and Hebridean rocks. These appear to pass up gradually into the last-named group, so that it is difficult to draw a sharp line between them, though, as before, type specimens of each are very distinct, the one being very hard, tough, often breaking readily across the banding, the other, whiter, commonly more micaceous, friable and fissile.

Each of these groups is characterized by a general constancy in the size of the constituents in typical examples, so that there is a marked increase in coarseness from (1) to (3). This may be roughly represented by saying that the diameter of grains of the same mineral will be as the numbers 1, 2, 3.

(4) A study of the geological map of the Austrian Alps suggests

that the second series in several places is very imperfectly represented, and that there is a great break at the base of the first, and this accords with what may be observed in the field.

These conclusions, as will be seen from the former part of this paper, and from my remarks in 1886, may be extended to the whole Alpine chain.

In many parts of Switzerland, especially in the Pennine and Lepontine Alps and in Northern Italy, a series of micaceous, calcareous, and chloritic schists occurs, which appears to be the highest amongst the "slaty crystallines," which is lithologically identical with those described in this paper, and is assigned to a like stratigraphical position. It is true that the "*Thonglimmerschiefer*" group of the Tyrol is parted from the similar rocks of the Lepontine Alps by a great group of rock called the "*Bündnerschiefer,*" which some excellent geologists have referred to the Trias. These also I know, and while I will not deny that Triassic or even Palæozoic rocks may be infolded with them, I see no possibility of distinguishing the dominant members from those just mentioned, and no probability of their being of Mesozoic age. I am fairly well acquainted with rocks indubitably Mesozoic, both in Eastern Switzerland and in the Southern and Northern Tyrol. Generally calcareous, argillaceous bands are occasionally intercalated. These are never, so far as I have seen, more than slates, while the dominant limestones and dolomites are microscopically and macroscopically different from those associated with the upper schists. I have therefore no doubt that the Swiss geologists are quite right who regard the "*Bündnerschiefer*" as a continuation of the upper schist ("*Thonglimmerschiefer*" series) of the Tyrol and of the upper schist of the Central Alps. Again, the schists of the south-western Alps (above described), called by some authors *schistes lustrées*, have also been referred, though dubiously, to the Trias. Here, again, while I think it very possible that rocks of later date, especially of Carboniferous age, may be infolded, I can find no evidence in favour of, and much against, regarding the whole series as Trias or even as Carboniferous. This group, in the Western Alps, can be traced almost without a break into the "Upper Schists" of the Central Alps. I have again and again wandered over the Alpine region, and examined specimens from Monte Viso to the Gross Glockner, and find that the rocks, which appear from stratigraphical considerations to be the uppermost members of the crystalline series, possess characteristics in common, as above defined, and can be readily recognized as a distinct and well-marked group.

These are commonly succeeded, in descending order, by a great group of mica-schists and fine-grained gneisses, of which we may take the Lepontine gneiss for a type. These rocks are more coarsely crystalline than the others. The mica-flakes in the schists are larger, the limestones more coarsely crystalline. Sometimes, as on the south side of the St.-Gothard axis, it is difficult to draw a line between this group and the last described; but generally there seems to be a marked break, and occasionally the former appears to be

practically absent. In confirmation of this inference I may mention that the schists, to which, from their lithological peculiarities, I have given the name of the Tremola schists, appear to be rare in the Tyrol, in the French and in many parts of the Central Alps, and I have not yet seen them so fully developed as on the southern side of the St. Gothard.

Lastly, and seemingly lowest, comes the great group of strong (banded) gneisses and granitoid gneisses, which, as said above, sometimes appears to graduate into the last-named. In the present state of our knowledge it is often difficult to identify this group with certainty, because we are ignorant of the history of its more granitoid members. Nevertheless, we find banded gneisses of a "Laurentian" aspect in the French Alps and the Central Tyrol, and in some parts of Switzerland; and even if the granitoid members—such as the great *massif* of the Central Oberland—are (as I believe them to be in many cases) granites subsequently modified, and so igneous in origin, these are curiously like the granitoid rocks which elsewhere are grouped with Laurentian and Hebridean rocks, and are unlike the granitoid rocks which in other parts of the Alps are associated with the above-mentioned groups. This, to say the least, is a remarkable coincidence.

The result, then, of my examination has been to confirm the view, expressed in my Address, that, broadly speaking, a stratigraphical succession can be detected in the gneisses and schists of the Alps, and that these rocks are of Archæan age. There have also been some negative results. It has been confidently asserted that between the second and third groups in the Alps an important one should be intercalated, to which the name of Pietra Verde has been given. It has been defined as distinguished by "the frequent presence therein of serpentine, diorite, diabase, and related rocks of a greenish colour"*. As most of the Alpine serpentines are altered peridotites, as diorite and diabase are igneous rocks, it is obviously necessary, before taking these as characteristics of a geological group of stratigraphical value, to show that they are contemporaneous in origin. This, which one would have thought would have appeared to any competent petrologist a necessary preliminary, has not been done, and, as I know well, it cannot be done. The group is also said to contain crystalline limestones, which, however, so far as I know, are very local and not readily separable from their associated gneisses and schists, so that I have been unable to find any rocks at this horizon which can be formed into a definite group. It is, indeed, true that hornblendic rocks appear to be rather common just about a particular horizon; but these occur so sporadically that anyone who regards them as of stratigraphical value is bound to prove that they are not intrusive. Serpentine certainly is of no value as marking an horizon in the Alps, for it occurs very commonly in the Upper Schist. It has, indeed, been asserted that the serpentines are sometimes, both here and in the Apennines, insular masses of

* "Geol. Hist. of Serpentine," Trans. Roy. Soc. Canada, vol. i. p. 154.

older rock, on which the Upper Schists have been deposited. I think that the author of this hypothesis cannot have examined with any care the masses described in this paper, or he would have seen that these forerunners of the existing Alps must have been the most singular mountains which the world has yet known.

Even less reasonable, as it seems to me, is the proposed correlation of this "Pietra Verde" group of the Alps with the Huronian of Canada. If the former exists at all, it consists of highly crystalline rocks, and is overlain by a vast series of gneisses and crystalline schists. The latter is a great group of fragmental rocks *. In the most typical locality they are very slightly altered, and their origin is indubitable. Here and there it is true some schists occur, but under circumstances and with characters which justify the supposition that they are modified basic igneous rocks; but the rocks which occur in the Alps, at the so-called Pietra-Verde horizon, are highly crystalline, and their origin, if it be not igneous, is, at present, undeterminable.

To conclude: rocks of igneous origin, sometimes retaining their characteristics, sometimes subsequently modified, probably in consequence of pressure, occur indubitably at all horizons among the crystalline series of the Alps,—serpentine, pyroxenic, and granitoid rocks. But I cannot explain, and I believe that anyone who will read my description attentively will find it difficult to account for the principal members of the Upper-Schist group, if they are not altered stratified rocks. Mica-schist, quartz-schist, chloritic schist, calc-schist, and limestone pass one into the other, and are associated exactly as sandstone, shale, and limestone in an ordinary clastic series. The minor mineral bands—the stratification-foliation—are parallel with the apparent direction of bedding thus indicated, and I can only explain them as resulting from the deposition of materials of variable chemical composition, subsequently altered into different minerals. I have elsewhere shown † that from indubitably stratified rocks, banded schists, which, in their mineral association, though not in their minuter structure, exactly resemble the schists of this group, have been produced by the action of intrusive igneous masses. If, then, we prefer to attribute these structures to some modification produced by pressure, such as shearing or rolling-out of a complex of igneous rocks, we desert, as it seems to me, inductive reasoning for imaginative and gratuitous hypotheses.

In the middle group, or the Lepontine type, the origin of the various members is less readily determined; nevertheless, rocks of variable mineral characters are associated in a way which, at any rate, resembles that of stratified masses. Many of the gneises exhibit bands characterized by different minerals, especially quartz, felspar, and mica, which closely resemble those in members of the upper series, though all the constituents are more coarsely crystalline. Hence,

* The typical district north-east of Lake Huron is now well known, having been admirably described by the late Professor Irving (Amer. Journ. Sci. vol. xxxiv. pp. 204, 249, 365). I have also seen something of it myself (Quart. Journ. Geol. Soc. vol. xliv. p. 32).

† Quart. Journ. Geol. Soc. vol. xliv. p. 11.

even if we admit an igneous origin for a larger proportion, and assign a more important *rôle* to dynamic metamorphism, it is very difficult to explain the regular banding of many members, occurring, it must be remembered, not locally, but in thick masses over extensive areas, by anything but an original structure due to some kind of stratification.

In the lowest series, the question of origin becomes yet more difficult. The foliation of many important masses is very probably a superinduced structure, due to subsequent earth-movements. The mineral banding in others may result from movements in a plastic mass anterior to consolidation, modified also by subsequent disturbances; so that an igneous origin is possible for many rocks which are lithologically true gneisses. Still the universal application of this hypotheis would, I think, sometimes land us in serious difficulties, and I find it difficult to account for certain coarse crystalline limestones which appear to me to graduate, though quickly, into coarse mica-schists and gneisses, if they have not originated in some kind of sedimentation or precipitation.

In February 1886, on resigning the office of President, I laid before you the conclusions in regard to the crystalline schists, at which I had arrived after some years of special study. The result of the work described in this paper, supplemented by visits to Cornwall, Brittany, Normandy, and the Channel Islands, and the study of specimens from other localities, while it has cleared up some difficulties, and removed some minor misconceptions, has confirmed the main conclusions which I then expressed as to the Archæan age of the gneisses and schists which are included under the three types described in this paper. While I quite admit the possibility and, in some cases, the probability that many of them, especially among the more coarsely crystalline, are modified igneous rocks, I am of opinion that where the modification has been followed by complete recrystallization, it goes back, as a rule, to Precambrian ages; so that, even if the rocks have become schists in consequence of mechanical stresses, we may rightly speak of them as Archæan schists. This, at any rate, is the result of my studies in the Alps:—that while the earth-movements to which these crystalline rocks have been subjected, not only during the mountain-making of the existing chain, but also in the interval between the Trias and the Carboniferous periods, and probably anterior to the latter (the first, at the present day, being the most conspicuous), have modified the structures, and in some cases have blotted out all record of the previous history of the rock, the latter is an occurrence comparatively rare and local. To learn to read this palimpsest of Nature's stone book is, no doubt, a task which requires long and laborious work. Study of the rock-masses in the field over extensive districts, study of carefully selected specimens with the microscope are indispensable. We must remember that, like those who are engaged in deciphering ancient inscriptions and reconstructing an ancient language, we are feeling our way, and are in constant danger, owing to the imperfection of our data, of drawing incorrect conclusions; neverthe-

less, making every allowance for this, I believe, even after the fog which arose from Burlington House last September, that the more important of the results mentioned above are not very far from the truth.

IV. APPENDIX.

Descriptions of Microscopic Structures.

A. Western Alps.

(a) *Schists of the Combe de Gavet.*

(*a*) *Strong Mica-schist near the Octroi de Vizille* (fig. 8).—This rock (p. 71) chiefly consists of mica, kyanite, and quartz. The first mineral varies from a brown, strongly dichroic mica, to a very pale

Fig. 8.—*Pen-and-ink Diagram of Schist from near Octroi, Vizille.* (× 29 diameters.)

(A) kyanite showing linear enclosures. The divergence of these bands in the grains is more marked in some other parts of the slide, which, however, were not otherwise so well fitted for representation.

straw-coloured mineral (the more abundant). The latter exhibits no marked dichroism, but gives rich colours with crossed nicols. This mineral may result from a "bleaching" of the brown mica, by separation of the iron constituent; but I am doubtful whether all of it can thus be explained. The kyanite occurs in grains, from sub-

angular (sometimes four-sided) to somewhat rounded in outline, often about ·03″ wide. They contain tiny flakes of brown mica, black granules, and (much more abundantly) minute belonites, which, with low powers, appear quite black, but with high powers are seen to be translucent and of a pale dull tint. These last are sometimes so abundant as to completely discolour parts of a grain of kyanite. They are arranged in roughly parallel lines or streamers. The quartz occurs commonly in clustered grains, with the usual habit of mica-schist. All the constituents suggested that the rock has been considerably modified by pressure subsequent to its first consolidation. The mica is often beautifully bent and puckered; the kyanite sometimes appears to have been broken and otherwise disturbed in position. This also seems indicated by the fact that the dusky black lines mentioned above, while generally lying approximately in the same direction in the slide, are sometimes markedly divergent, as though a grain or a fragment of a crystal had been twisted out of its original position. If I am right in regarding these enclosures in the kyanite as anterior to the mechanical disturbance, it would seem highly probable that they were in some way a record of a differential arrangement of constituents prior to the first formation of the mineral, and belong to a very early epoch in the history of the rock.

(*b*) *Schist with contorted Quartz-veins by the entrance of Livet* (p. 72).—This rock chiefly consists of quartz, mica, garnet, and felspar. The first mineral calls for no special remark. The mica is mainly biotite, but there are a few flakes of a pale mica, as above described. The garnets are small, often about ·02″ in diameter, roundish in outline, of a pale reddish or yellowish-brown colour, but often darkened with dusky enclosures, and frequently showing one rather marked cleavage. But little felspar can now be identified, and that is plagioclase; but many of the quartz-grains are full of "dusty" particles, as if replacing a felspar. The rock has evidently undergone mechanical disturbance, but is not notably crushed. As the above description shows, it is intermediate between a mica-schist and a kinzigite.

(β) *Gneiss of the Combe de Malasal, &c.*

(*a*) *Gneiss in the glen West of Freney* (p. 72).—The rock consists of quartz, felspar, mica, and some epidote. The last occurs in granular streaks, and is clearly of later origin. The mica varies from brown to nearly colourless, and occurs in rather small flakes; the felspar is rather decomposed, but a plagioclase and probably orthoclase can be recognized. The structure of this rock has been much modified by pressure; in many parts, the original grains of quartz and felspar have been broken up into a "mosaic" of granules, and I think the mica has similarly suffered. Thus it is very difficult to decide upon the antecedent condition of the rock, but I think that its constituents were banded, and the relations of the quartz and felspar were those usual in an old gneiss, not in a granite; *i. e.* I

believe it (and this agrees with the impression formed in the field) to have been a gneiss of the Laurentian type.

(*b*) *Gneiss, 4 kil. West of La Grave* (p. 75).—The constituents are as above described, except that there is little or no epidote, but a few very small, almost colourless garnets are present. The mica, however, occurs in larger flakes, and evidently is mostly biotite more or less altered. The structure of the rock has been modified by pressure, but the original one is retained more distinctly than in the former case. It is that of a very old gneiss, not of a normal granite.

(*c*) *Gneiss from glen below the Meije Glacier* (p. 77).—The differences from the last described are only varietal.

(γ) *Carboniferous Series near Le Freney.*

(*a*) *Matrix of the Conglomerate, east side of village* (p. 74).—This is mainly composed of small fragments, which are cemented by a minutely flaky or granular material of paler dusty grey colour; probably the latter largely consists of mica, produced by the decomposition of pulverized felspar. Here and there is a fair-sized flake of white mica. The fragments occasionally contain felspars of fair size, about ·05″ long, but the matrix of these, and the whole of the rest, consists of a mottled mosaic of quartz, apparently traversed by thin wavy bands, chiefly of the above-mentioned microscopic mica. Their structures suggest a derivation from a gneiss or schist that has been greatly crushed and sheared. As these structure-lines point in all directions in the slide*, it is difficult to refer them to Post-Carboniferous movements. The neighbouring rock, however, when in its normal conditions, appears to be the ordinary coarse crystalline rock described in Sect. I. It would seem therefore as if the fragments had not been derived from the immediate vicinity, and their structure was a record of Pre-Carboniferous disturbances.

(*b*) *The Slate west of the village* (p. 73) consists of fragmental quartz, commonly very angular; felspar, more or less decomposed; white mica, with (rarely) a little brown, and tourmaline (very rare). The rude cleavage-lines are darkened by the deposit of a carbonaceous substance, which is more or less disseminated throughout the slide. We have evidently here a rather fine detritus (the fragments rarely exceed ·01″ in diameter), derived from a crystalline series. The mineral changes in the rock, since Carboniferous times, appear to me to have been extremely slight, yet, as stated above (p. 73), it is completely infolded between huge masses of crystalline rock, and must have been affected by Pre-Jurassic as well as by Tertiary disturbances.

(δ) *Calc-mica-schists East of the Watershed of the Cottian Alps* (pp. 80–82).

As stated in the foregoing paper, these rocks belong to one general type, the individual constituents being small grains or flakes, generally less than ·01″ in diameter (except in the cases of

* This is also true of the larger fragments.

the calcite), but the structure being truly crystalline. I have examined specimens from the following localities:—(*a*) by the road to Oulx, about half a mile below Cesanne; (*b*) associated with serpentine west side of Col de Sestrières; (*c*) succeeding the serpentine; (*d*) harder band in micaceous schist; (*e*) contorted schist at sketch (p. 80); (*f*) the dark schist below Champlain du Col. *b–f* are taken in order on the ascent of the west side of the Col de Sestrières.

Their chief constituents (excepting *b*) are quartz, calcite, and mica, the last sometimes brown, more often white, rendered in places almost opaque by black carbonaceous dust, which has a streaky, more or less banded arrangement, and is commonly associated with the mica. (*d*) contains a fair amount of dolomite and not much mica. All the slides indicate that the rocks have been subjected to considerable pressure, followed by a certain amount of mineral re-arrangement; but the form and mode of association of almost all the grains of quartz and calcite (or dolomite), and of the mica-flakes, is such as to convince me that the rocks, prior to the disturbances, were true crystalline schists. Microscopic study also has confirmed the opinion formed in the field, that the foliation was a record of stratification, and that the rocks are altered sediments. (*b*) differs from the rest. Its constituents are extremely minute, and the difficulty of examining them is increased by their feeble action on polarized light. The only distinct minerals, except a few granules of iron-oxide, are some fairly thick scales of a chlorite (average about ·005″ in the longer diameter) of a pale green colour and very weak depolarizing action. These are thinly scattered through a ground-mass, which appears to consist of minute chalcedonic silica (perhaps sometimes even of opal) and plates or belonites in great abundance of a very pale greenish-brown mineral. Evidently the rocks have been greatly compressed. This is indicated by the contortion of some tiny chalcedonic veins and the presence of a rude cleavage. It might be either an ordinary sediment greatly affected by pressure, or a rather fine-grained schist similarly modified. Further we know not how much alteration may be due to the proximity of the serpentine. Hence I can merely state the facts and say that, with my present knowledge, I cannot venture to draw any inference from this specimen. Crush a fine-grained schist, and crush a fine-grained mudstone, and you sometimes come locally to the same result, the difficulty of separation, be it noted, being chiefly due to the minuteness of the constituents.

(ε) *Gneisses of the lower part of Val Chisone* (p. 83).

These are grouped together as having much in common. The specimens examined are from (*a*) near La Mean (?), Commune de Rolle, (*b*) Quarry 1½ kil. above La Perouse, (*c*) Large quarry about 300 yards south of San Germano. The chief constituents are quartz, felspar, biotite, more or less epidote, and some iron-oxide, with garnet and zoisite as accessories. They agree generally in the fresh condition of the constituent minerals, and in the absence of signs of

recent crushing. The grains of quartz and felspar have a slightly wavy outline, and form a sort of mosaic or agglutination, and the two minerals are frequently difficult to distinguish. Microlithic enclosures are rather common, such as epidote, zoisite, and perhaps garnet. The constituents of the rocks exhibit a certain parallelism, but little approach to a true mineral banding. In (*a*) small garnets (reddish) are rather common, generally rounded in outline. The biotite more frequently passes into a pale greenish mineral, and a little pale hornblende may be present. Small grains and crystals of a mineral resembling epidote are numerous; some give the usual bright tints of that mineral, but many only afford low blues of the second order, with, as a rule, oblique extinction. Probably more than one variety of the mineral is present, and perhaps a little zoisite. In (*b*) there is more approach to a mineral banding; the mica is in better preservation; garnets are rare or absent. The normal epidote is rather abundant, with, however, the low-coloured variety, and some well-defined zoisite; (*c*) has a considerable amount of zoisite * with a little garnet and sphene. The peculiar structure of these rocks separates them from the ordinary gneisses and schists. It suggests the possibility of an igneous origin, which, in one case at least (*c*), is corroborated by the field-evidence. Pressure may have been an agent in the metamorphism, but it must have been followed by almost complete mineral rearrangement. The structure differs entirely from those exhibited in the granites, gneisses, and schists of other parts of the Alps, which we may reasonably consider the results of the great disturbances of Tertiary date. Moreover the foliation produced by these is, commonly, roughly parallel in its strike with the dominant trends of the ranges. Here, however, it runs almost at right angles to the direction which we should have expected, and which we actually found in the neighbourhood of the watershed. The natural inference, then, would be, that we are dealing here with a foliation of earlier date than the Tertiary disturbances.

B. Eastern Alps.

(*a*) *Central gneiss* (Von Hauer), *Velber-Tauern district* (pp. 89, 90).

Of the more hornblendic varieties, three specimens have been examined. In all, hornblende (normal), quartz, and more or less felspar are present, sphene is generally found, and more or less ferrite or opacite. The specimen "from the valley bed above the Tauern Haus" contains a little of a mineral resembling kyanite; it may be a modified dolerite or diorite, but the structural change cannot be recent, complete mineral rearrangement having taken place. Another specimen, taken about 800 feet above Gschlöss, on the way to

* I have to thank Mr. Teall for enabling me to identify this mineral. As it happened, though I had an abundance of the so-called saussurite, I had no good typical zoisite in my collection.

the pass to Mittersill, contains also a fair amount of black mica, the flakes being without definite orientation, also a little epidote. The remark just made applies also to this specimen. A "dark variety" from near the summit contains more epidote; the quartz-grains give very distinct indications of an old crush-structure.

Two specimens of the more granitoid rocks which occur near the top of the pass have been examined. The ground-mass is a mosaic of quartz, felspar (rather decomposed), and occasional flakes of white or brown mica, in which occur streaky aggregates of quartz-granules, irregularly bordered grains, sometimes rather elongated, of felspar, in one specimen of microcline or of orthoclase, in another probably of plagioclase. These occasionally contain rounded inclusions of quartz, flakes of brown or green mica, and in one case (rather abundantly) of white mica. The structure of the rocks indicates modification by pressure, but at no recent date, for the consolidation is complete. Anterior to that, it may have been either a normal granite or a gneiss of Laurentian type.

(β) *Mica-schist and Gneiss* (Von Hauer) (pp. 86, 89, 94).

I have examined but few specimens microscopically, because, in one case, I believe the gneiss to be a modified granite, in others because the specimens were not collected *in situ*. As it happened, I did not actually cross extensive outcrops of the group, though I saw its rocks frequently in moraines and torrent-débris, as well as in the Innsbrück Museum. It may suffice to say of these that, as a rule, had they been shown me as coming from the St.-Gothard district, I should have seen no reason to doubt the statement. The specimens examined came from the base of the Rauberberg, from near St. Johann and Landeggsäge, in the Iselthal, and from Matrei on the Brenner. They all contain quartz, white and brown mica, and garnets, with some felspar, the constituents being commonly about ·02″ in diameter, sometimes a little more.

The details of their accessories, and the minor structures, are of no general interest; (*a*) and (*c*) give indications of mechanical disturbances subsequent to the production of their foliated structure; (*b*) is not quite so markedly foliated or banded.

(γ) "*Thonglimmerschiefer*" *series* (*Thonschiefer, &c. of* Von Hauer).

As intimated in the text, the rocks of this widely spread series may be roughly grouped under five lithological divisions—(*a*) the quartz-schists and quartzose mica-schists, (*b*) the lead-coloured mica-schists, which appear to be the most characteristic of the series as a whole, (*c*) the calc-mica-schists, (*d*) the crystalline limestones, and (*e*) the green schists. These groups may be briefly described as follows:—

(*a*) This rock is chiefly composed of quartz-grains of rather irregular outline, which with crossing nicols commonly exhibit a differently tinted border, and of flakes of a colourless or very pale

greenish-grey mica, which are often about ·01″ long, the former being sometimes a little larger. Here and there is a little ferrite and (rarely) a cluster of minute mica-films, with perhaps one or two very small colourless garnets. The structure suggests that the rock has been to some extent sheared by pressure. It bears a general resemblance to certain of the quartz-schists of the "newer gneiss" series of the Highlands, especially those which seem less affected by the results of the overthrust. It is difficult to say how far the mica is a secondary product; I incline to regard it as in the main anterior to the pressure-modification, but to some extent subsequently recrystallized; for the outline of the flakes is commonly distinctly rectilineal.

Of the more micaceous varieties, specimens have been examined from the quarry near Brunecken (p. 85), and from above the castle on the route from Mittersill to Kitzbühel (p. 91). Both consist mainly of quartz and mica, chiefly colourless or very pale green. A few grains may be felspar or kyanite. Among the microliths, zircon and rubite are probably present. In the former rock the mica is often slightly coloured, and the bands are frequently more or less ferrite-stained, sometimes rendered almost opaque. Both have evidently been much disturbed subsequent to the first foliation; the former, as described, shows a cleavage-foliation superinduced on a stratification-foliation. The latter has been so much crushed that the first-named foliation dominates, while the latter can only here and there be traced. As might be expected, the quartz constituent varies in size, much of it being quite minute. This gives the rock at first sight a clastic aspect, but I have no doubt this is secondary —the result of crushing. At the same time I believe the rock to have begun its history as a sediment, though the original constituents can no longer be recognized.

(*b*) Specimens of this group have been examined from various localities. Perhaps the most characteristic are those from the entrance of the Iselthal (p. 86), and from near Steinach on the Brenner (p. 94). The chief constituents are quartz and mica, the latter commonly white, but occasionally pale green. The Iselthal specimen contains a fair amount of hydrous green mica or chlorite and more or less "ferrite" with a little kyanite. The Steinach specimen has its mica associated with considerable quantities of opacite, so that the slide is in parts streaked with black. Grains of kyanite are fairly abundant. This rock, in short, has a remarkable resemblance to some of the lead-coloured schists from South Devon *. Evidently it was once a foliated rock, with alternating quartzose and micaceous bands; these have been crumpled and "vandyked," and a strain-slip cleavage developed in parts, parallel, of course, with the cleavage-foliation, which now dominates in the mass. The Iselthal specimen has a similar history, though it is not quite so markedly banded. Specimens from the Zillerthal and from the ascent from Kitzbühel are a little more quartzose, and brown mica seems more

* Quart. Journ. Geol. Soc. vol. xl. p. 1, & vol. xliii. p. 715.

abundant. In these, cleavage-foliation dominates, though traces of the stratification-foliation can be detected. As a rule, they have been almost pulverized, the bulk of the slide consisting of minute chalcedonic quartz and minute mica, green or brown, with an occasional nest of granular quartz, or a large flake of mica, which seems to have escaped destruction. The more micaceous varieties from the last locality are so crushed that I have thought it useless to have them sliced, as I have no doubt as to their nature.

(*c*) Three specimens examined. They consist of variable amounts of calcite, mica, generally almost or quite colourless, and quartz, with a little iron-oxide in grains. All exhibit a cleavage-foliation posterior to the crystallization of the constituents ; that on the ascent from Windisch-Matrei (p. 87) has more quartz and less calcite than the others; it is rather discoloured with ferrite and opacite and contains several granules of a discoloured brown mineral looking not unlike a garnet, but with double refraction—perhaps rutile—also, I think, a little zircon. In the specimen associated with the green schist from the higher part of the same glen (p. 88), calcite and dolomite predominate over the other constituents, and there is, I think, a little kyanite. In that from the quarry beneath the castle at Mittersill calcite predominates, and there are several grains of a mineral which is probably epidote.

(*d*) Five specimens examined. Rather compact white marbles :—(α) from the east end of the Castle Rock, Brunecken, (β) from base of Weissenstein, Windisch-Matrei, (γ) pale grey finely crystalline marble from quarry under castle, Mittersill. Very compact fissile grey marble from near Maierhof, Zillerthal, (δ) from near bridge above Maierhof, (ϵ) from the Calvarienberg. (α) consits mainly of calcite, (β) and (γ) are more strictly dolomite. Besides these carbonates there are only a few small flakes of white mica, a few granules of quartz or of some colourless silicate, and a little ferrite. (δ) contains a little more mica, and the calcite is rather " dirty "-looking. (ϵ) has still more mica, rather larger and more abundant granules of quartz and, perhaps, of a silicate which I cannot identify.

All have been subjected to great pressure. This is indicated by the variation in size of the grains of the calcite (or dolomite) and the fragmental aspect of the larger, which occur either isolated or in groups cemented by a mosaic of the smaller grains. The former also have one cleavage strongly developed, and occasionally exhibit twinning. Mechanical disturbance is most marked in (δ) and (ϵ). Now I have always noticed in the Alps that the proverb " noscitur a sociis " holds in regard to schists and limestone. If certain macroscopic characters are present in the former, the latter exhibits a certain aspect *. But the limestones in the upper part of the Zil-

* I have found this hold good in every region which I have hitherto examined, though I admit that a limestone is more liable to mislead than almost any other rock, except perhaps a quartzite. Limestones of comparatively recent geological age, when altered by igneous rocks, sometimes closely resemble the marbles of Archæan age. At the same time I believe, as the result of what I have noticed, that further study would reveal differences.

lerthal at once struck me as rather abnormal. They were more compact, less saccharoidal, than I had been accustomed to see, when they were among crystalline mica-schists. The microscope shows that this is due to the rock having been more or less pulverized and subsequently recemented, so that its texture bears some resemblance to that of the Mesozoic Alpine Limestones. Perhaps I should add that I am well acquainted with the Tyrol dolomites, and that they differ in some respects from all the rocks described in this paragraph, macroscopically and microscopically. Further, it is only at Brunecken that any doubt could arise as to the geological horizon of the limestone; but here, I think, its relations to the schists and its position with regard to the neighbouring dolomites becomes clear on examination.

(*e*) Four specimens, α, β, γ, from the gorge above Windisch-Matrei (p. 87), δ from the ravine near Mittersill (p. 90). All contain chlorite, often in flakes about ·02 inch long. Possibly more than one species is present, but most of it is of a yellowish green with transmitted light, a fairly bright sap-green with vibrations perpendicular to the vertical axis, and a kind of straw-yellow with those parallel with it, and the extinction appears to indicate a mineral of the hexagonal system. Yellowish epidote is also present in variable quantities. In (α), from the top of the mass, the epidote in parts of the slide occurs in minute granules, with a "dusty" look, rendering the structure obscure, but in other parts in well-defined grains and prisms, often about ·01 inch long. There are some characteristic crystalline grains of kyanite, containing the dark enclosures with linear arrangements described above (p. 100), and occasionally small grains of epidote. A little quartz and some grains of iron-oxide occur, with much opacite lying along the lines of cleavage-foliation. In (β), from some distance down in the mass, almost half the slide consists of somewhat rounded grains about ·02 inch in diameter, of a clear mineral containing numerous minute flakes of chlorite and granules of epidote. These constituents exhibit a rough parallelism throughout the slide. It is rather difficult to decide upon the nature of this clear mineral, but some grains are twinned, and it appears to one to correspond better with kyanite than with a felspar. There are a few grains of an iron-oxide, probably hæmatite, and in one part is a little dolomite or possibly chalybite. (γ) epidotic schist underlying the interband of calc-schist. In parts of this, epidote is abundant and well developed. The supposed kyanite occurs, but there is certainly some quartz, and crystalline grains of hæmatite (?) are more common. (δ), from near Mittersill, seems to have rather more quartz, calcite, and iron-oxide than the others, with less epidote; but the differences appear to me only varietal. These rocks all give evidence of mechanical disturbance subsequent to the first crystallization.

I am indebted to Mr. E. Greenly for the following analyses of varieties of these chloritic schists, made in the chemical laboratory at University College:—

	No. I.	No. II.	No. III.
SiO_2	43·48	50·80	47·44
Al_2O_3	14·54	23·08	15·26
Fe_2O_3	10·20	6·44	4·42
FeO	7·87	4·09	8·36
CaO	6·29	4·75	5·29
MgO	11·11	1·70	12·15
K_2O+Na_2O..	2·68	4·50	4·58
H_2O........	2·51	3·55	2·27
CO_2	·97	·62	·75
	99·65	99·53	100·52

No. I. (β) of above description. No. II. (γ) the same.
No. III. (δ) the same.

Nos. I. and III. indicate that the composition of the rock is not very different from that of a basalt, and suggest the possibility that the original material might be a basic tuff. The analysis of No. II. is nearer that of some ordinary argillaceous rocks, and may indicate that the original material was a clay with perhaps a slight admixture of basic ash. A detailed study of No. I. seems to indicate the probability of a fair amount either of free quartz or of a silicate with a higher percentage of SiO_2 than kyanite being also present, if the identification of the last mineral be correct.

Discussion.

The President said that the paper was a valuable addition to studies which the Author had made especially his own. By adopting three instead of four groups he had simplified the classification. It was clear that in the Alps, as elsewhere, there was at the base of the Archæan a series of highly gneissic rocks, whilst in an upper division were indications which could only be reconciled with the idea of aqueous deposition. It was noteworthy that the Author had not countenanced any hypothetical parallels with Archæan rocks on the other side of the Atlantic.

Mr. Teall commented on the great divergence of opinion between the Author and geologists like Heim. The former, he considered, held exceptional views, though there was evidence in his papers of increasing faith in dynamic metamorphism. The Author claims to be able to distinguish between Archæan schists and later rocks; the opposite school asserts that rocks of later date have been reduced to the condition of crystalline schists.

As a test case, he would mention the discovery of Belemnites by Charpentier and Studer in the garnetiferous mica-schists of the Nufener Pass and Fontana. Dr. Grübenmann of Frauenfeld had recently given an elaborate petrographical description of these rocks.

As regards the lower division, it was held that primary foliation

in many cases did not date from a period extremely ancient, but rather from the period of upheaval. Lawson declares that certain of the banded gneisses of Canada, hitherto known as Laurentian, are intrusive igneous masses. M^cMahon also had pointed out the intrusive character of gneissic masses of the Himalayas. In the above remarks he had put forward the views of other people, but his own work had led him in the same direction, and he concluded that there was no safety except on the solid ground of rational uniformitarianism.

Dr. Hicks denied that there was any evidence in this country of such metamorphism of the newer rocks on a large scale. We were told that these crystalline schists may be of any age. Though there are fossils in an altered rock at one spot, this surely is not evidence enough to tempt us to regard the whole of the non-fossiliferous portion as necessarily of Jurassic age. Why should the fossils be present at one place and entirely absent in all the rest of the area if the rocks are of the same age?

Mr. Bauerman was sorry that there was not more expert-knowledge available for the discussion of the paper. Heim's results were, he believed, obtained in the Central Alps, and not in either of the districts under review. He was not acquainted with the eastern section brought forward by the Author, but that across the Maurienne appeared to him to represent the structure of the country as he had seen it.

Prof. Blake remarked that Heim distinctly stated that his region of the Alps was not suited to determine the succession of the schists, but that Lory, who had studied the same district as the Author, found there a true stratigraphical sequence; he also inquired with regard to the Silurians shown on the map, if the schists are anywhere seen to underlie these.

Dr. Geikie, while acknowledging the unwearied industry of the Author, expressed his doubts as to the success of attempts to make out an order of succession among the crystalline schists, except upon very detailed work. As regards the Alps, it is a fact that Belemnites occur in a truly schistose garnetiferous rock. The evidence of Heim and others went to show that infoldings of Jurassic rocks had become truly crystalline. The question to be settled was how much of the crystalline schists of the Alps were originally sedimentary rocks.

The Author, in reply, said that the grouping had been somewhat reduced, but that he had always been doubtful with regard to the *pietre verde*. He accepted the issue as stated by Mr. Teall, for he had fully expected to hear of the Belemnites; he had not been profoundly impressed by the views of Mr. Lawson; and had always admitted the possibility of some of these structures having been subsequently produced. His faith in dynamic metamorphism had certainly increased, but that was no reason why he should allow it to become a superstition. But he maintained that these banded structures were different from those produced by the last great movements in the Alps. Throughout the whole of the Alps certain

types of rock form the floor for both the Trias and the Carboniferous. With respect to the so-called Silurians in the map, there was a marked difference between them and the schists, and they could be distinguished by careful observers ; but he had not seen the schists actually underlying them, as he had not followed the outcrop eastward.

If Heim was right, he was wrong ; but from his knowledge of the districts, he thought it probable that these alleged cases were infoldings of Jurassic rock in the older crystalline series just at these points, and that it would be found there was a very important difference between the Belemnite-bearing rock and the true garnet-schist which he had described on a former occasion.

5. Description *of a* new Species *of* Clupea (C. vectensis) *from* Oligocene Strata *in the* Isle of Wight. By E. T. Newton, Esq., F.G.S. (Read November 21, 1888.)

[Plate IV.]

Mr. G. W. Colenutt, of Ryde, has recently been investigating the Oligocene strata of the northern parts of the Isle of Wight, and an account of his researches appeared in the August number of the 'Geological Magazine'*. Among the numerous fossils he has obtained from these deposits, none are more interesting than the small fishes which occur, apparently in some numbers, in a grey shaly clay belonging to the "Osborne Series," at King's Quay and other localities. The best examples, which Mr. Colenutt kindly sent me for examination, vary in length from 20 to 60 millimetres. Most of them have the back concave and the mouth wide open, seeming to indicate that they died in a state of tetanus, probably due to asphyxiation, as their condition is very similar to that of fishes which have died from being kept in too small a quantity of water.

Many of these fossil fishes are beautifully preserved, with the vertebral column, ribs, fins, and tail in their natural positions. The heads also are present, but unfortunately they are all more or less mutilated, so that the forms of the bones cannot be well deciphered.

The large examples, of which there are four well preserved (Pl. IV. figs. 1, 2, 3), measure from 43 to 58 millimetres in length. These vary somewhat in form, as will be seen from the examples figured; but this is probably due to pressure, as they seem to be precisely alike in other particulars. The single dorsal fin has 14 or 15 rays, and is placed as nearly as possible in the middle of the fish, the front rays being midway between the tip of the snout and the base of the tail. The ventral fins are directly under the front rays of the dorsal fin and about midway between the pectoral and anal fins. In only one example can I count the rays of the ventral fin, and this has eight or nine. The pectoral fin is seen in two or three specimens, and in one of them it has nine rays, the longest reaching about halfway to the ventral fin. The vent is situated midway between the ventral fin and the base of the tail; and the anal fin, which has sixteen or seventeen rays, extends from the vent for about two thirds of the distance between the latter and the base of the tail. The tail itself is deeply forked and has about twenty rays.

The scales seem to have been very thin, and are in all cases too much broken to allow anything definite to be said as to their form and structure. One or two specimens, however (figs. 1, 2), give some idea of their size, and it seems probable that there were about nine in a row between the dorsal and ventral fins, and perhaps forty or fifty between the head and tail. To the naked eye the scales seem to be devoid of ornament, but with the aid of a microscope

* Dec. iii. vol. v. p. 358 (1888).

delicate concentric ridges may be seen. There are no traces of a lateral line.

One of the most striking features in the structure of these fishes is the row of strong spines which extends along the ventral margin from the pectoral arch to the vent. There are ten or eleven of these spines between the pectoral and ventral fins, and ten or eleven between the latter and the vent. One, if not more, of the specimens shows some of the spines extending in front of the pectoral fins. Each of these abdominal spines consists of a horizontal plate, shaped like a ploughshare (Pl. IV. fig. 1 *c*), with a free strong point directed backwards, supported on each side by a vertical triangular plate, strengthened in its middle by a ridge. In fact these spines are similar to those found in the Herring and Sprat, but are proportionally stronger. In the Herring the median spine and its lateral plates are in one piece; but in these fossils the lateral plates so frequently separate from the spine at the same place, as to give the appearance of a definite division at this point. Two of the larger specimens have the vertebral column so well preserved that one can count in them respectively forty and forty-one vertebræ, of which fourteen or fifteen are caudal. None of the specimens have the head sufficiently perfect to show its precise form; but the outlines of some of the separate bones may be traced, and the close resemblance between these and the corresponding parts in the Herring and Sprat make it tolerably certain that in the form of the entire head they also resembled those fishes. The mandible is deep in proportion to its length, and the oral margin nearly vertical and seemingly devoid of teeth. Parts of both maxillæ are shown in one specimen (fig. 1 *b*), and it will be seen that while the proximal end is slender the distal part expands into a broad plate, and this is overlapped by an accessory maxillary bone of an oval shape, the upper end of which is broken; but there can be little doubt that, when perfect, it was continued into a slender process forming with the oval plate a battledore-shaped bone, as in the Herring. The quadrate bone is shown in one specimen, and has very nearly the form of an equilateral triangle. The anterior half of the parasphenoid is a slender style, widening out where it comes to underlie the brain-case; but none of the specimens show how it terminated posteriorly. The upper and lower parts of the preoperculum are nearly at right angles to each other (fig. 1 *a*); the outline of the bone, however, cannot be traced. The junction of the operculum with the suboperculum forms an oblique and nearly straight line; not horizontal, as in the Pilchard, or sigmoid, as in the Herring. Whitebait, which are said to be young Herrings, have the sigmoid curve only slightly marked. The gillrakers are long, as shown in the specimen represented by figure 2.

The bones of the tail (fig. 7) are arranged on the same plan as in the Herring and Sprat *. The hindermost vertebra is continued upwards and backwards into a style supported by lateral processes; the

* See Journ. Quekett Club, ser. 2, vol. i. p. 79 (1882).

hæmal arch of the same vertebra is strong, and, extending downwards and backwards, forms the lowest hypural bone; above this may be seen, in two of the specimens, two broad triangular plates with a space between them, seemingly occupied by another and narrower plate; thus the positions of four hypural bones are indicated. In one of the specimens, above the uppermost triangular plate, may be seen the positions of two, or perhaps three, narrow ones; so that one may trace the position and, to some extent, the form of six, if not seven, plates corresponding with those which have been described in the tail of the Sprat and arranged in the same manner.

The smaller examples of these fossil fishes (figs. 5, 6) are from 20 to 25 millimetres in length, and, at first, I thought might belong to a second species, as the dorsal fin, in some of them, seemed to be placed more forward, and the number of vertebræ which could be counted was never more than thirty-seven or thirty-eight (fourteen or fifteen being caudal); but upon carefully measuring the specimens, and making some allowance for crushing in fossilization, I felt that these differences were insufficient for specific distinction. The number of rays in each fin and the number of abdominal spines seemed to be the same in both. The smaller specimens are therefore provisionally referred to the same species as the larger.

If the characters given in the above description be compared with the diagnoses of the Clupeidæ given by Dr. Günther *, there will, I think, be no question as to these Oligocene fishes belonging to the genus *Clupea*; and, indeed, they agree so closely with the recent British species that it may be well, in the first place, to notice some of the points in which they differ from them.

In the Oligocene fishes the dorsal fin has its anterior rays midway between the end of the snout and the base of the tail, while the ventral fin is placed below its anterior part. *Clupea harengus* also has the dorsal fin in this position; but the ventral fin is below its middle part. *C. pilchardus* has the dorsal fin placed more forward than in the fossils, and the ventral is again below its middle part. *C. sprattus* has the ventral fin below the anterior rays of the dorsal fin, as in these fossils; but the dorsal fin itself is further back.

Dr. Günther gives sixty-one species of *Clupea* in his British Museum Catalogue; but of these, only seven have the ventral fins opposite the anterior rays of the dorsal fin, namely, *C. sprattus*, *C. argyrotænia*, *C. aurea*, *C. arcuata*, *C. palasah*, *C. melanura*, and *C. lile*. All of these differ from the fossils under consideration in having the anterior rays of the dorsal fin either nearer the head or nearer the tail. The position of the dorsal fin in the last two of the above species is given by Dr. Day in his 'Fishes of India,' 1878.

It is evident, therefore, that although the Isle-of-Wight fossil fishes belong to the genus *Clupea* †, and are closely allied to some

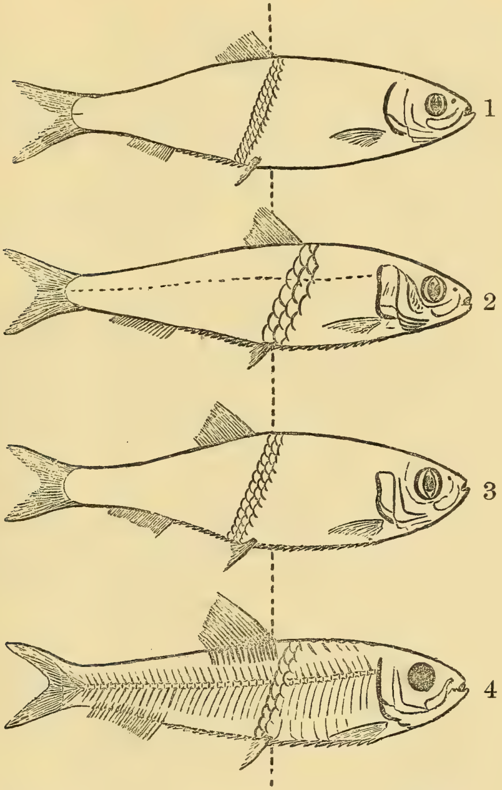
* Catalogue of Fishes in the British Museum, vol. vii. p. 381 (1868).

† [NOTE. 10th Jan., 1889.]—The remarks made by Mr. A. Smith Woodward, when this paper was read, have led me to re-examine the fossils with special reference to the anterior dorsal region, and the appearances seem to be more in favour of the presence of scutes in front of the dorsal fin than I had thought.

of the recent species, yet they cannot be referred to any one of them.

Among the fossil species of *Clupea* which have been recorded, I have been unable to find any form precisely agreeing with Mr. Cole-

Outline Diagrams of Species of Clupea *to show the different positions of the Dorsal and Ventral Fins. The vertical dotted line is placed midway between the end of the nose and the base of the caudal fin.*



1. *Clupea harengus*, $\times\frac{1}{4}$. 2. *Clupea pilchardus*, $\times\frac{1}{4}$.
3. *Clupea sprattus*, $\times\frac{1}{2}$. 4. *Clupea vectensis*, nat. size.

nutt's specimens from the Isle of Wight, although some of them appear to be closely allied. *Clupea Beurardi* and *C. minima* from

I find also, in some of the specimens, bones in front of the dorsal fin and above the neural spines similar to those in *C. Fontannesi* (see page 116), and something like the broad neural spines in *Diplomystus analis*, Cope (Rep. U. S. Geol. Surv. Terr. vol. iii. plate 7, fig. 4, 1884). I should like to have better evidence, however, before referring the Isle-of-Wight fishes to *Diplomystus*.

Lebanon, and *C. dentex* from Murazzo Strutiano *, are somewhat like, but not so near, I think, as some of the recent forms.

C. Beurardi has the head proportionately much larger: *C. dentex* has the ventral fin under the middle of the dorsal, and the latter is further forward than in our fossils; *C. minima*, although agreeing with our fossils in the position of the dorsal fin, has only 29 vertebræ.

Hermann v. Meyer † described a number of specimens of *Clupea* from the Lower Miocene clay of Unterkirchberg, Ulm, and for these he established three new species—*C. humilis*, *C. lanceolata*, and *C. ventricosa*. The first two of these species are much like the Isle-of-Wight fossils; but the differences which they present prevent our specimens being referred to either of them. *C. humilis* differs in having 43 or 44 vertebræ, of which 20 or 21 are caudal. Further the dorsal fin has only 12 rays, and the ventral fin seems to be placed further back.

C. lanceolata comes nearer to the Isle-of-Wight specimens in having from 38 to 40 vertebræ, but differs inasmuch as 19 of these are caudal; and, moreover, the dorsal fin is placed somewhat further back, and the ventral fin is under its middle.

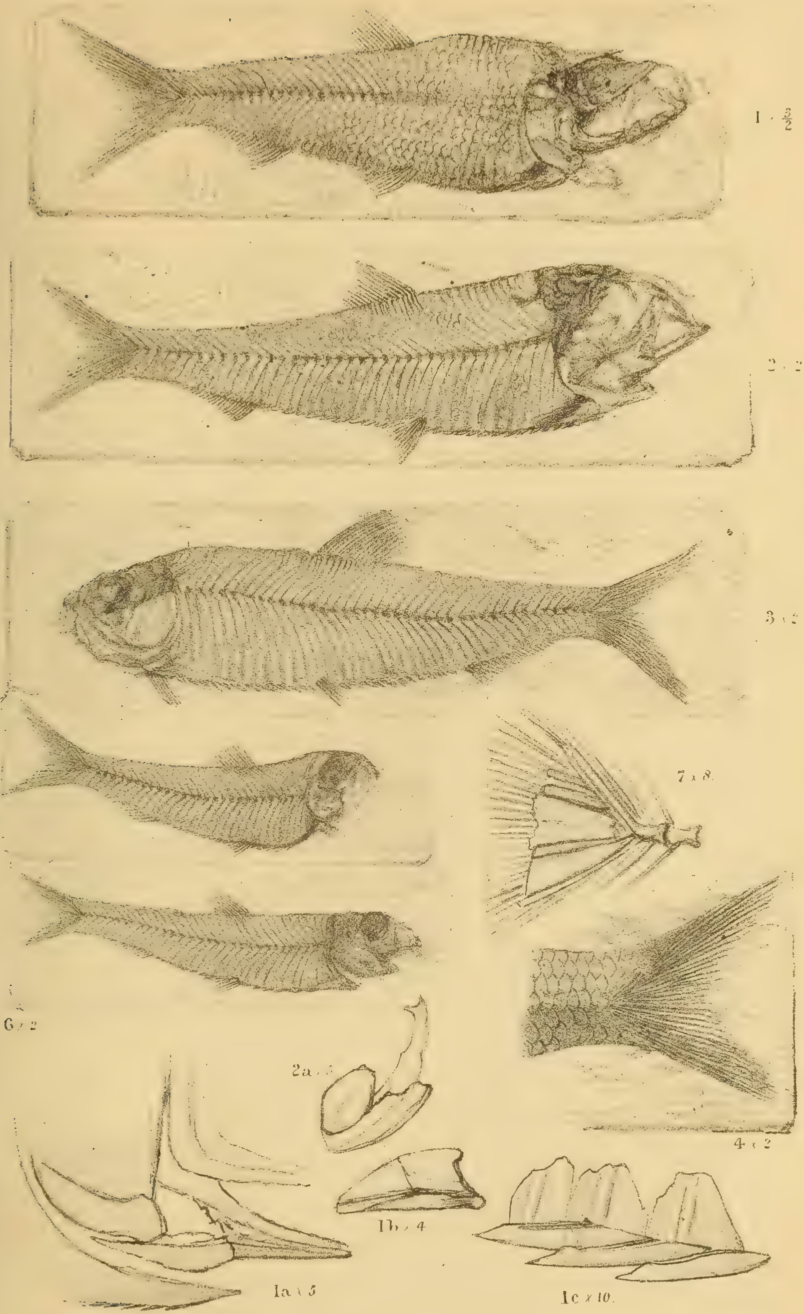
One of the small specimens figured by H. von Meyer ‡, and placed by him, with doubt, in the species *C. humilis*, agrees very closely with the smaller Isle-of-Wight specimens, and may perhaps belong to the same species.

M. H. E. Sauvage described several species of *Clupea* from the Miocene of Licata, in Sicily §, and one of these ‖ bears a close resemblance to the smaller specimens from the Isle of Wight; but although the relative positions of the fins and the number of the vertebræ seem much the same, yet the vent is differently placed, as is shown by the number of caudal vertebræ; for M. Sauvage counted 20 caudal and 17 abdominal vertebræ in the Licata form, while in the Isle-of-Wight specimens there are only 14 or 15 caudal, and from 23 to 25 abdominal vertebræ.

C. Fontannesi, from the Upper Miocene, also described by M. Sauvage ¶, has 51 vertebræ, of which 19 are caudal, and the front rays of the dorsal fin are nearer the snout than the base of the tail.

Several small species of *Clupea* have been recorded by Sign. P. Lioy from the Monte Bolca beds**, and by Baron Achille de Zigno ††; but the descriptions of the species are insufficient for comparison, being little more than measurements of length and height, the positions of the dorsal and ventral fins not being stated.

* Agassiz, 'Poissons Fossiles,' vol. v. pl. 61, figs. 1, 2, 4.
† Palæontographica, vol. ii. p. 85 (1851).
‡ *Loc. cit.* pl. 14. fig. 8.
§ Ann. Sci. Géol. vol. xiv. 1873.
‖ *Loc. cit.* pl. 13. fig. 75.
¶ See "Note sur les Poissons Fossiles d'Eurre, Drôme," in Fontannes's 'Période Tertiaire dans le Bassin du Rhône,' part vi. 'Le Bassin de Crest,' p. 205 (1880).
** Atti Soc. Ital. Sci. Nat. vol. viii. p. 410 (1865).
†† Atti R. Inst. Veneto di Sci. ser. 4, vol. iii. (1874).



F. H. Michael del. et lith.

Mintern Bros. imp.

CLUPEA VECTENSIS.

All the species of *Clupea* alluded to by Kramberger from the Tertiary of Croatia * have a greater number of vertebræ than the Isle-of-Wight specimens, except *C. heterocerca*, which has the dorsal fin placed more forward, and *C. arcuata*, Kner, which has a much larger head.

As I am unable to refer these Isle-of-Wight specimens to any known species, I propose to name them *Clupea vectensis.*

Although the genus *Clupea* has been obtained from numerous European localities, and also from Asia, in beds ranging from the Neocomian to the Miocene, yet it does not appear to have been hitherto recognized as a fossil in Great Britain.

EXPLANATION OF PLATE IV.

Clupea vectensis, new species from the Osborne Beds of the Isle of Wight, in the possession of Mr. G. W. Colenutt, of Ryde.

Fig. 1. Specimen from Ryde House.
1 *a*. Opercular apparatus of same specimen. *op*., operculum ; *sub. op*., suboperculum ; *i.p*., interoperculum ; *p.op*., preoperculum ; *cl*., clavicle ; *br*., branchiostegal ray.
1 *b*. Mandible from left side of same specimen.
1 *c*. Three abdominal spines and plates.
2. Specimen from Ryde House.
2 *a*. Maxillary bones of same specimen.
3. Specimen from King's Quay.
4. Tail of a specimen from King's Quay, showing scales.
5. Small specimen from Ryde House.
6. Small specimen from King's Quay.
7. Bones of the tail of a specimen from Ryde House.

DISCUSSION.

The PRESIDENT was not surprised at the discovery of a *Clupea* in freshwater beds.

Mr. WHITAKER had suggested that the discoverer should send the specimens to Mr. Newton, and congratulated himself upon the result. It was another case of the advantage of having good local observers.

Mr. A. SMITH WOODWARD thought he could distinguish a series of small dorsal scutes in some specimens, and inquired as to the Author's interpretation of the appearances. Most of the Eocene Clupeoids of the United States exhibited such scutes, and formed the genus *Diplomystus*, Cope. If the British fossil proved to be of the same type, the fact would be specially interesting, for, in the Old World, *Diplomystus* had hitherto been detected only at Mt. Lebanon.

The AUTHOR thanked the speakers for their remarks. Whether or not any dorsal scutes occurred was uncertain ; in some there seemed to be roughening. He thought it better to leave the specimens in the genus *Clupea.*

* "Die Jungtertiäre Fischfauna Croatiens," Mojsisovics and Neumayr's Beitr. Paläont. Œsterr.-Ungarns, Bd. iii. p. 65 (1884).

6. *On the* Jersey Brick-Clay. By Andrew Dunlop, M.D., F.G.S. (Read December 19, 1888.)

A fine yellow clay which occurs in Jersey and in at least some of the other Channel Islands has received little attention from geologists, and the few who have noticed it appear to have considered it merely the result of local weathering. This clay is more or less sandy, and though generally of a dull yellow colour, is sometimes reddish orange. On microscopic examination many of the grains are seen to be somewhat rounded, but the majority of them have sharp angles. In one or two situations the clay effervesces freely with acids, and at some places on the coast it has been found to coat the grass roots with a pipe-like covering. On a small detached island on the south-east coast it contains fantastically-shaped concretions like the "*Männchen*" of the Rhenish löss. This, however, is probably due to the fact that above the clay at this point there is a bed of shells, all modern, from which carbonate of lime has been washed down by rain. Sometimes the clay exhibits obscure marks of bedding, and at one point in the town of St. Helier, where an excavation had been made for relaying some drains, I noticed distinct lamination. Mr. Green, a well-sinker, has also told me that, in sinking wells, he has often noticed distinct stratification. The lower part of the clay often contains angular stones, sometimes grouped together pretty closely, sometimes at some distance from each other, while occasionally a single stone, or one or two, may be noticed, with no others within some distance. These stones generally vary in size from an inch or two to about a foot in their longest diameter, but now and then a piece of rock two or three feet or more in its greatest length may be noticed. In most cases these stones lie with their longest diameter parallel to the surface of the rock below, but often they are observed to be more or less upright. One section shows a layer of small stones running for about six or eight feet, and some feet above the bottom of the clay. All these fragments are of the same nature as the subjacent rock, or are derived from some rock bed far distant.

The rocks of the island are chiefly igneous, viz. granite, diorite, rhyolite, quartz-felsite, and a trachytic-looking porphyry; but an argillaceous shale, in places hardened and altered by heat, is found largely developed over considerable areas, and a conglomerate consisting of fragments of this rock is found on the north-east corner of the island. The later geology is represented by raised beaches and by submerged forest-beds and peat. There are two well-marked raised beaches between fifty and sixty feet above mean tide-level; and there is a cup-shaped depression, apparently the section of a gulley, at the top of the rocky side of a granite outlier, some 150 feet above mean tide-level, which contains a deposit of well-rounded pieces of granite, as well as other angular blocks.

The clay, which occurs in patches here and there all over the island, and sometimes spreads over extensive areas, is found on all the rocks, and covers the raised beaches. The highest mentioned, which is on the top of the cliff at the South Hill Fort, is filled up with it. It is thickly and widely spread over the highest parts of the island, and at one or two points it is used for brick-making. Mr. Copp, one of the principal brick-makers, states that where he works he gets a depth of from ten to thirty feet, and that a little to the north of his works a well was sunk through fifty feet of the clay. It also attains great thickness in many parts of the lower ground, where the original deposit has been added to by rain-wash.

Under the town of St. Helier it overlies a blue clay, which varies in thickness from one to thirty feet. Mr. Green gives the following section found in sinking a well in the town:—

Yellow sandy clay	15 feet.
Large angular gravel	15 inches.
Stiff blue clay	27 feet.
Blue sand with somewhat rounded pebbly rock .	A few inches.

It seems, on the whole, to cover a greater and more continuous area in the north and centre of the island, the highest parts, while there is little to be seen over most of the south-western corner. The same clay is found on the opposite coast of Normandy and in the other Channel Islands, but I have not examined it in these localities.

From the fact that the same clay is found over different rocks, from the fact of its covering the raised beaches and lying over the blue clay, as well as from the position in which many of the stones it contains lie in it, it seems improbable that it can be the result of disintegration *in situ*. Besides, the fine yellow sandy clay, though it might be the product of the disintegration of the clay-shale, which is often arenaceous, or of the felsitic rocks, has little resemblance to disintegrated granite, on which, indeed, it may sometimes be seen lying. It seems to me most probable that it is a fluviatile deposit, laid down during, or at the close of, the glacial period, when the rivers, flooded in summer time by the melting glaciers, spread over large tracts of country the muddy débris with which they were highly charged. At that time the Channel Islands were united to the mainland, and in all probability the clay was deposited at the same time as, and, in fact, forms part of one of the brick-earths of Northern France.

There is, however, another view that might be taken; such a clay could be produced by the decomposition of the clay-shale, of the felspathic porphyries, and of the rhyolite; some sections seem to show this going on, and the clay is, I think, more developed over those rocks.

Perhaps, then, the long-continued subaerial decomposition of those rocks may have produced the material which has been washed away and spread out by the action of water. If this were the case, however, the moving force must have been a greater and more extensive flow than that of ordinary rain-wash. For example, La

Motte Island, a mass of diorite, has about fourteen or fifteen feet of the clay on it, some three hundred yards below high-water mark, without the slightest trace of decomposition in the subjacent rock.

This theory refers to Jersey alone. How it could be made applicable to the other islands and the coast of France, I do not know.

Discussion.

The President would not like to give a decided opinion without seeing the rocks, but he was disposed to regard the clay as the result of rain-wash.

Dr. Morison observed that in a case where the clay was resting on granite, there being a well-marked line of demarcation between them, and the underlying granite being quite undecomposed, it could not be the result of disintegration *in situ*.

Rev. E. Hill had seen an analogous clay in Guernsey, where it was clearly the result of decomposition of gneiss *in situ*. In a specimen of vitrified brick, made from this clay, the original minerals were not very much altered. He spoke of the great age of the land-surfaces in the Channel Islands.

7. Notes *on the* Radiolaria *of the* London Clay. By W. H. Shrubsole, Esq., F.G.S. (Read November 21, 1888.)

Microscopical examination of London Clay from wells in Sheppey and elsewhere, and from pit-sections at the same horizon in different parts of the London Basin, continued for some years, has afforded proof of the existence near the base of this formation of a Diatomaceous zone, which was constant so far as the examination extended. It yet remains for some one to ascertain whether this zone continues throughout the full extent of the London-Clay area. The list of specimens given in my paper "On the Diatoms of the London Clay" (Journ. Royal Micr. Soc. vol. i. p. 381) has since been considerably enlarged by Mr. Kitton and others, from washings supplied by myself.

In a paper "On the New Town Well at Sheerness" (Proc. Geol. Assoc. vol. v. p. 355), I had previously called attention to 60 species of Foraminifera and some other microzoic forms not specifically mentioned. Among these latter were some reticulated fragments suggestive of Radiolaria, but no specimens occurred sufficiently perfect to be described. My friend Dr. Bossey, F.R.M.S., of Redhill, was more fortunate in this respect than myself, for in 1881 he saw and sketched a Radiolarian skeleton, apparently nearly perfect, which he had found in some London-Clay washings sent to him by me.

The formation of a well for the Queenborough Cement Company in 1885, near the Railway Station, gave me another opportunity of searching for new forms of Tertiary life. In accordance with previous experience, after passing through a zone rich in Foraminifera, a few solitary Diatoms only were found, until at 225 feet from the surface the Diatoms occurred in great abundance in brightly glittering patches, causing the clay to assume a somewhat laminated character.

On washing some of the clay from this level, I found not only the familiar Diatoms, but also some fairly good specimens of Radiolaria. This material I distributed among correspondents, and have not been able to get any more.

Fortunately Mr. A. L. Hammond, F.L.S., had, with his usual exactitude, made sketches of some specimens he had seen.

I had sent some of the Radiolarian material to Prof. Ernst Häckel, with regard to which he says that "he found a large number of fragments of Tertiary Radiolaria, and but few well-preserved specimens. These appertain to the three families of Sphæroidea, Discoidea, and Cyrtoidea, and seem to be identical with those described in 1880 by Emil Föhr, from the Tertiary beds of Grotte in Sicily *. There is no new species among the recognizable forms, but perhaps there may be among the numerous fragments."

Wanting more precise information as to the species, and being unable to find in the 'Palæontographica' any forms similar to those I had found in the London Clay, I sent Mr. Hammond's sketches to

* See 'Palæontographica,' vol. xxvi. 1880, p. 71.

Prof. Häckel, respecting which he wrote, on Dec. 6, 1885:—"The Radiolarians of the London Clay, the sketches of which I return enclosed, are not identical with any species known, living or fossil. I can therefore give only the names of genera enumerated in my 'Prodromus,' published in 1881 *.

"Fig. 11, *Cenosphæra*, sp. (Monosphærida); figs. 2 and 2*b*, *Spongodiscus*. Figs. 1, 8, and 10 are Cyrtida, probably Monocyrtida (with a single joint); Fig. 1 perhaps the upper part of a *Cyrtocalpis*, figs. 8 and 10 of an *Anthocyrtis* or *Cornutella*.

"But when there are two joints separated by a transverse stricture or an internal flange (as you describe), it may belong to Dicyrtida (*Sethocorys* or *Anthocyrtis*, the latter with a corona of terminal spines). The large spines in your figs. 5*a* and 5*b* may be apical spines of those or of other Cyrtida, or perhaps radial spines of Sphærida.

"If the apex and the mouth of the shell is not complete, it is not possible to determine with certainty the genus of Cyrtida.

"Since Radiolaria occur in great numbers in all seas (in warmer, however, more frequently than in colder), and in open seas as well as near the shore, no certain inferences can be drawn from their presence in the London Clay."

From the above correspondence, it appears more than probable that in the material sent to Prof. Häckel there were some forms that I had not seen. In the absence of specimens or further information, nothing more can now be said respecting them, and attention must therefore be restricted to those forms of which we have the representations.

Nos. 1, 8, and 10 evidently belong to the same species, No. 1 having been less perfectly preserved than the others. These, in some washings, were more abundant than the other forms, and were first found alone at a slightly higher level.

The shell may be described as being conical, with a curved outline, terminating in a solid apical spine tapering to a point, this spine in many specimens being longer than in those figured. Whereas in many of the Cyrtoidea the apical spine is set obliquely to the centre of the shell, in all specimens of the species under consideration that I have examined the spine is a direct prolongation of the longitudinal axis.

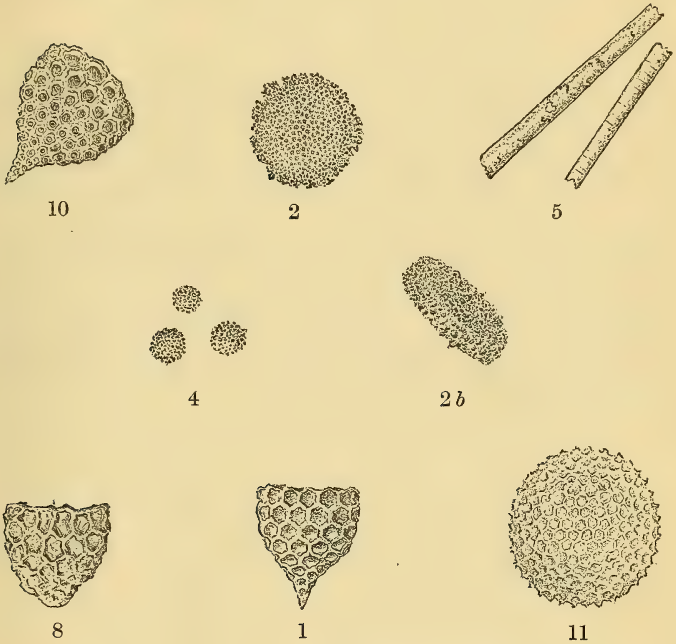
Basal mouth a simple wide opening. Skeletal shell built up of lattice-work, having openings which are hexagonal on the exterior, and circular on the interior surface, and which increase in size towards the mouth. Near the open end is a broad internal flange, pierced with circular holes proportionately large, as if to combine lightness with strength. In many instances the mouth is ornamented with a corona of short spines, which seem to have been removed from others (and from those figured) by abrasion; and in a few I observed traces of a probable further extension of the framework on a larger scale.

* Jenaische Zeitschrift für Naturwissenschaften, vol. xv.

In the absence of full proof that a second joint had existed, I think it better to refer the specimens to *Eucyrtidium*, and I record the species under the name of *Eucyrtidium Hammondi.*

Another and abundant form, Nos. 2 and 2 *b*, has the appearance of a discoidal Diatom, abraded circumferentially, witht his difference—the cellulation differs from that of any Diatom known to me, and there are no indications of bivalvular formation. A sectional view shows that the same structure prevails throughout. Any doubt on the point is set at rest by Häckel, who distinctly refers it to the Radiolarian genus *Spongodiscus.* I have named it *Spongodiscus asper.*

Radiolaria from the London Clay of Sheppey.



1, 8, 10. *Eucyrtidium Hammondi*, sp. n., ×112.
2, 2 *b*. *Spongodiscus asper*, sp. n., ×112.
11. *Monosphæra toliapica*, sp. n., ×112.
4. Spherical bodies, probably Radiolarian, ×112.
5. Fragmentary rods, probably Radiolarian, ×112.

No. 11 represents a globular form of hexagonal lattice-work, the interior being now filled with pyrites; I refer this to the genus *Monosphæra*, under the name of *M. toliapica.* As suggested by Häckel, the fragmentary styles or rods, Nos. 5 *a* and 5 *b*, probably represent some complex forms that have failed to preserve their

integrity. Though completely pyritized, they present very smooth, even polished surfaces, indicative of their former siliceous condition.

The pseudomorphic change to pyrites seems to have been as complete in these Radiolarians as in the Diatoms from the same formation.

Sponge-spicules were present in nearly all the washings I examined, and in some material from the Queenborough Well, sent to Prof. W. J. Sollas, F.G.S. &c., he recognized some characteristic Tetractinellid forms, one, like the spicules of *Stelletta*, being a trifid fork with bifurcated rays, and another like the calthrops common in *Pedastrella*.

I have to acknowledge the kind assistance rendered by T. Spenser Smithson, Esq., of Rochdale, in mounting the specimens exhibited.

Discussion.

The President observed that the particular advantage of a paper like the present is that it shows the value of searching. He doubted the advisability of coining new names.

Dr. Hinde asked whether the Radiolaria were uniformly pyritized; also whether the sponge-spicules had undergone a similar change.

Prof. T. Rupert Jones commented on the rarity of fossil Radiolaria. Some few have been found in the Chalk. Their pyritization would tend to their ready destruction.

The Author, in reply, said that he was not anxious to apply new names. He was doubtful whether any silica remained in the sponge-spicules or the Radiolaria, although some has been detected in the Diatoms.

8. *On* ARCHÆOCYATHUS, *Billings, and on other* GENERA, *allied to or associated with it, from the* CAMBRIAN STRATA *of* NORTH AMERICA, SPAIN, SARDINIA, *and* SCOTLAND. By GEORGE JENNINGS HINDE, Ph.D., F.G.S. (Read December 19, 1888.)

[PLATE V.]

THE real characters and the relations of the group of fossils known generally under the term *Archæocyathus* are at present subjects of discussion among palæontologists; they have been regarded as allied to Foraminifera, Sponges, and Corals. Many of the forms occur in the lowest fossiliferous zones of the Cambrian rocks, and are thus among the earliest known forms of life, a fact which gives additional interest to their study. Since Mr. Billings first called attention to them in 1861, they have been investigated by several authors, more particularly by Sir J. W. Dawson, Prof. Ferd. Römer, Mr. C. D. Walcott, and, more recently, by Dr. Bornemann; but it cannot be said that the obscurity attaching to them has been fully cleared up. I have been induced by Sir J. W. Dawson to undertake an independent investigation of their characters, based more particularly on their microscopic structure, and, thanks to the kindness of the above-named authors, I have been supplied with material which has enabled me to ascertain by direct comparison the nature of these fossils from widely separated localities. Thus Sir J. W. Dawson sent some specimens from Labrador belonging to McGill College Museum; the Geological Survey of Canada, through Mr. J. F. Whiteaves, F.G S., supplied me with the type forms described by the late Mr. Billings; Prof. Ferd. Römer with the figured specimens of *Archæocyathus marianus* from Spain; and to Dr. J. G. Bornemann I am indebted for fragments of rock filled with these fossils, which he collected in the Island of Sardinia *.

The microscopic sections which I have prepared from these specimens show tha tthe organisms originally included in *Archæocyathus* vary considerably in structure, and cannot properly be included in a single genus, and it is owing to this fact that much of the uncertainty respecting the real nature of the genus has arisen. With the view of clearing up the subject, I have in this paper described, in considerable detail, the microscopic and other features of the different species originally referred to *Archæocyathus*, as well as of other forms which have been considered to be allied to it; I have removed from the genus, and placed in other genera, the forms which do not generically correspond in structure with its type species, and I have discussed the relationship of these different fossils to Corals and Sponges respectively.

* Since this paper was read before the Society, Mr. C. D. Walcott has kindly sent me specimens of *Ethnophyllum*, Meek, from Nevada, and of *Coscinocyathus Billingsi*, Walcott, from Labrador.—(G. J. H., Jan. 24, 1889.)

1. *History of the Genus* Archæocyathus *and allied forms.*

Mr. Billings's first notice of *Archæocyathus* appeared in 1861, in the first part of a work entitled 'New Species of Lower Silurian Fossils.' The specimens were from the Potsdam Limestone Formation at Anse au Loup, Labrador; they were regarded as possessing some of the characters both of Corals and Sponges, and the following were given as their generic characters:—"Turbinate simple or aggregate, cup deep. The internal structure, so far as can be made out, consists of an inner wall constituting the inner surface of the cup, and an external wall or epitheca enveloping the whole. Between the two walls there are numerous radiating septa, the interseptal spaces being filled with poriferous or cellular tissue. It is highly probable that the inner wall is permeated by pores communicating with the interseptal tissue." Two species, *A. atlanticus* and *A. minganensis*, were included in the genus, and the first of these was figured. Shortly afterwards, the description and figures were reproduced in the 'Geology of Vermont,' vol. ii. Appendix, pp. 944–946 (1861).

In 1865, the entire volume, of which the part published in 1861 was only a fragment, appeared under the title of 'Palæozoic Fossils,' and in this Mr. Billings considerably modified his references to *Archæocyathus*. A new name, *A. profundus*, is given to forms previously referred to *A. minganensis*; these are figured and placed first as the type of the genus, whilst *A. atlanticus* is relegated to a secondary position. The generic diagnosis remains unaltered, but it is stated that since 1861 the Author had discovered numerous silicified spicula in a specimen of *A. minganensis*, and that these fossils must therefore be classified amongst the extinct tribes of sponges. In the latter part of the volume (pp. 354–357) the generic characters, as illustrated by *A. minganensis*, are again referred to, and figures are given of this form and of the spicules found in connexion with it. It is stated that no spicules had been discovered in *A. profundus* and *A. atlanticus*, but their absence is attributed to the fact that no silicified forms of these species were known. The author finally concludes that all three species belong to one generic group * closely related to *Calathium*, Bill., a genus of siliceous sponges.

* It will be shown in the sequel that each of these species belongs to a distinct genus; and the question then arises, for which of them the generic name of *Archæocyathus* should be retained. In the usual course of proceeding the species first described, *A. atlanticus*, would bear the generic name; but in the reprint of the original description in 1865, the author removes this from the first place, and substitutes *A. profundus* as the type. The reason for this is evident. One of the main features in the diagnosis of *Archæocyathus* is the possession of radiating septa, and in *A. atlanticus* such structures cannot strictly be said to be present, whilst they are extremely well marked in *A. profundus*; consequently the former species cannot be retained in the genus without completely altering the generic characters given by Mr. Billings, whilst these fully agree with *A. profundus*. Since no other author treated of the genus in the interval between the first description and the subsequent alteration and correction, it seems only fair and reasonable to allow the same right to the author, to amend his own mistake, which would be conceded to an independent writer; and I propose therefore to adopt as the type of the genus the form which was so designated by Mr. Billings, viz. *A. profundus*.

Dr. J. W. Dawson *, on the other hand, found a structural resemblance to Foraminifera in the microscopic characters of *A. atlanticus* and *A. profundus*.

In 1868 †, Prof. Meek described as the types of a new family of corals some fossils from the Cambrian rocks of Nevada, for which the genus *Ethmophyllum* was proposed. Shortly afterwards ‡, the same author stated that they were probably not generically distinct from *Archæocyathus*, Bill., since they agree very closely in internal structure with *A. minganensis* and *A. profundus*. No definite diagnosis was given of *Ethmophyllum* apart from the specific characters, and no figures accompanied the paper. It seems probable, however, that the species described by Prof. Meek included more than one generic type, since it is stated that in the interior of some there were observed appearances of transverse plates, whilst in others there was a dense vesicular tissue. Mention is also made of obliquely directed canals passing through the inner wall, which in transverse sections appear as a double row of vesicles—structures which are not found in any of Mr. Billings's types.

In 1873 § Mr. S. W. Ford proposed the genus *Archæocyathellus*, and in 1878 ‖ the genus *Protocyathus* for some small imperfectly preserved forms from the Cambrian strata of Troy, New York. They are admittedly very closely allied to *Archæocyathus*, and the generic characters are mainly based on the nature and arrangement of the pores in the outer surface of the wall, features which, though of specific, are hardly of generic importance.

In 1876 ¶ Prof. de Koninck refers doubtfully to *Archæocyathus* some fossils from the Palæozoic strata of Australia, supposed to be of Devonian age. Judging from the description and figures, no definite opinion can be formed as to their real characters.

In 1878 ** Prof. H. A. Nicholson places *Archæocyathus* among the Spongida, referring more particularly to the spicules found in connexion with *A. minganensis*. Though, as will be shown in the sequel, this particular species is a true sponge, it is radically different from *A. profundus*, which is taken as the type of *Archæocyathus* proper.

In 1879†† Prof. v. Zittel places *Archæocyathus* together with *Calathium* in the Euretid family of Hexactinellid sponges; he states, however, that their structures are unknown and their true position doubtful. At a later date ‡‡, the view of F. Römer, mentioned below, is given, but without comment.

* Can. Nat. and Geol. 1865, p. 103, note; also quoted by Billings in Pal. Foss. vol. i. p. 356.

† Amer. Journ. Sci. and Arts, 2nd ser. vol. xliv. (1868), p. 62.

‡ *Id.* vol. xlvi. (1868), p. 144.

§ *Id.* 3rd ser. vol. v. (1873), p. 211, fig. 1.

‖ *Id.* vol. xv. (1878), p. 124, figs. 1*a*, *b*.

¶ Recherches sur les fossiles paléozoiques de la Nouvelle-Galles du Sud, 1876–7, p. 68, pl. ii. fig. 1.

** Manual of Palæontology, 2nd ed. (1878), vol. i. p. 139.

†† Handbuch der Pal. vol. i. 2nd pt. (1879), pp. 173, 195.

‡‡ *Id.* Appendix (1880), p. 728.

In 1880* Prof. Ferd. Römer treats at some length of the characters of *Archæocyathus*, and gives a minute and full description, accompanied by figures, of a new species, *A. marianus*, from the Cambrian strata of the Sierra Morena, Spain. This form shows the same remarkable feature of obliquely extended canals opening into the central cup, which Meek describes in *Ethmophyllum Whitneyi*. Römer accepts Billings's generic diagnosis, and places *A. minganensis* and *A. profundus* as the typical forms; the spicules found in connexion with the first named are regarded as accidental inclusions from disintegrated sponges. The genus, however, is considered to be allied to *Receptaculites*, Defr., and the perforated vertical radiating septa are compared with the so-called vertical pillars in this latter genus.

In the Cambrian strata of the Island of Sardinia, *Archæocyathus* and its allied forms are extraordinarily abundant; they were at first regarded as Corals allied to *Cyathophyllum*, but afterwards Prof. Meneghini † recognized their relationship to *Archæocyathus*.

To Dr. J. G. Bornemann, however, is due the merit of making an extensive collection of these fossils in Sardinia, and subjecting them to microscopic study ‡. Preliminary notices of the results appeared in various publications between 1881 and 1884, and full descriptions and figures in 1886 §. The author included in *Archæocyathus* proper, forms with a finely porous outer surface and a coarsely perforated inner surface and radial vertical septa dividing the interspace into longitudinal compartments, thus mainly of the type of *A. profundus*, Bill. A second genus, named *Coscinocyathus*, comprised forms which, in addition to the vertical septa, are furnished with regular transverse partitions or tabulæ, thus further subdividing the vertical compartments. In a third genus, *Anthomorpha*, irregular delicate transverse lamellæ are developed between robust vertical septa, and the walls and septa are further of a non-perforate character. Another provisional genus, *Protopharetra*, includes forms composed of fibres of homogeneous calcite. These are regarded as merely the vegetative developmental stage of *Archæocyathus*, from which the perfect cup-like forms of this genus are produced. These various genera are placed by Dr. Bornemann as a special division of the class Cœlenterata, the Archæocyathinæ, in the vicinity of Sponges, Anthozoa, and Medusoid polyps.

Nearly contemporaneous with the final memoir of Bornemann, an extended notice of the same group of fossils was given by Mr. C. D. Walcott‖. This author does not recognize the amended descrip-

* Lethæa Palæozoica (1880), pp. 298–303.

† Atti della Società Toscana di Sc. Nat. (1881), p. 201.

‡ Compte rendu du Congrès géologique international de Bologne, 1881, p. 221; Zeitschrift d. deutsch. geol. Gesellsch. xxxv. (1883), pp. 270–274; *ibid.* xxxvi. (1884), pp. 399, 400; *ibid.* pp. 702–706.

§ "Die Versteinerungen des Cambrischen Schichtensystems der Insel Sardinien," Nova Acta der kais. Leop.-Carol. deutschen Akad. der Naturforscher, Bd. li. No. i. pp. 28–78, tab. v.–xxxiii.

‖ "Second Contribution to the Studies on the Cambrian Faunas of North America," Bulletin of the United States Geological Survey, No. 30 (1886), pp. 72–89, pls. i.-v.

tion of Mr. Billings, and regards *A. atlanticus* as the legitimate type of *Archæocyathus*. But as it is impossible to make *A. atlanticus* conform to the generic diagnosis given by Billings, Mr. Walcott radically altered it for the purpose, and thus it is only nominally the same genus which Mr. Billings described.

The structure of *A. atlanticus* is described by Mr. Walcott as consisting of a more or less irregular system of rounded and irregular passages or canals, many of them terminating as *culs-de-sac* or little chambers in the mass of the skeleton. In longitudinal section the skeleton is stated to be arranged on arching transverse lines, and vertical and slightly radiating lines, but its minute structure is unknown. If spicula existed in *A. atlanticus*, they were probably destroyed by the crystallization of the calcareous matter of which the skeleton now consists; but in *A. Billingsi*, a new species, spicula are stated to be present in the interseptal spaces, the cup, and about the specimens, and are regarded as constituent parts of the organism. The author gives for the first time a separate definition of the genus *Ethmophyllum*, Meek, and figures the type forms. The skeleton is said to consist of fine branching spicula in one species (*E. minganensis*), and undetermined in others, owing probably to the replacement of the parts by calcite. Both *A. profundus*, Bill., and *A. minganensis*, Bill., are by this author included in Meek's genus, and it comprises also *Archæocyathellus*, Ford, and *Protocyathus*, Ford. All these forms are regarded as sponges, and the spicula, in several of the species, are supposed to have been lost in the crystallization of the calcite.

In 1886 * Prof. C. Schlüter compared some fossils from the drift of Sadewitz in Silesia to *Archæocyathus*, but their state of preservation is altogether too imperfect to allow of any satisfactory conclusions as to their structure or relations.

In the May number of the 'Geological Magazine' for the present year (1888), p. 226, I described the detached siliceous spicules present in specimens of *A. minganensis*, and referred them to several distinct species of siliceous sponges; consequently, as Mr. Billings had suspected, they did not belong to the form with which they are found. I also expressed the opinion that the so-called branching spicules were probably only siliceous replacements of the outer surface of the wall of the fossil, but I had not then seen specimens of these; from a subsequent examination of the type forms it is evident that they are genuine spicules belonging to the form itself, and thus the opinion I expressed about them was erroneous.

2. *The Mineral Nature of* Archæocyathus *and its allies.*

The mineral nature of this genus, whether calcareous or siliceous, has not been specially referred to by previous writers, though it has been implied that the present condition of some of the specimens is not the original one, and that if siliceous examples of these were

* "Archæocyathus im russischen Silur?" Zeitschr. deutsch. geol. Gesellsch. (1886), pp. 899-909.

found, they would show spicules. Mr. Walcott has likewise referred to the probable obliteration of the spicules by the crystallization of the calcite of which their skeletons now consist. It is therefore desirable to ascertain if possible the original mineral structure of these fossils in considering their probable zoological relations. First, however, we may exclude the *Archæocyathus minganensis*, Bill., from present consideration, since, as will be shown later on, this organism is undoubtedly a siliceous sponge, and has no relationship whatever to *Archæocyathus* proper and its allied genera. All the forms of this group which I have seen, whether from North America, Spain, or Sardinia, are uniformly composed of carbonate of lime. The Canadian specimens of *A. atlanticus* and *A. profundus* from Labrador consist of a dull white or yellowish-white carbonate of lime, compact in texture and opaque, unless in very thin sections, when it shows a very minute granular character. The specimens are imbedded in a hard compact granular limestone, reddish in tint and containing numerous microscopic fragments of various organisms. This matrix usually infills the cups and some of the interloculi in the specimens, but the interior spaces frequently are now filled with crystalline calcite.

When weathering has taken place, the matrix proves more resistant than the walls and septa of the fossil, which consequently are now indicated by depressed lines and furrows. In all the specimens which I have seen, the walls and other structures of the fossil are well defined and distinct from the matrix, and though from the lowest Cambrian strata, their characters are as clearly shown as if they had been of Mesozoic or Tertiary age.

The type specimen of *Archæocyathus marianus*, F. Römer, from Spain, consists, for the most part, of a dull, opaque, minutely granular carbonate of lime, similar to that of the Canadian specimens; but in the minutely reticulated outer surface of the wall, and in some of the septa as well, this has been replaced by a green mineral, not unlike glauconite in appearance. The matrix is a granular, calcareous, shaly rock, somewhat rusty by weathering. The spaces within the fossil are filled partially by the matrix and partially by crystalline calcite.

The Sardinian specimens vary somewhat in mineral characters according to the different localities from which they came. Those from Canal Grande occur as dark grey patches in a lighter matrix; the fossils themselves are of minutely granular carbonate of lime, and their interspaces are usually filled with crystalline calcite, and only occasionlly with the rock-matrix, which is a hard, compact, coarsely granular limestone with an admixture of mica and some other minerals. From this locality, and also from Punta Pintau, some of the specimens occur as casts in a coarsely granular micaceous rock. At San Pietro di Masua these fossils are enclosed in a reddish nodular marble with streaks and veins of calcite. They are whitish by ordinary light, and the carbonate of lime is minutely granular; their interspaces are filled with calcite. The specimens from Cucuru Contu have a dark appearance by reflected light; in

thin sections they are nearly transparent and composed for the most part of crystalline calcite. In a few cases they are of minutely granular carbonate of lime like those from other places, and even part of the same specimen may be granular and part crystalline. The rock-matrix is a finely granular carbonate of lime, of a brownish or reddish tint *.

From the above it is evident that the mineral constitution of *Archæocyathus* and its allied forms is of minutely granular carbonate of lime; and this is probably their original condition, since if these organisms had possessed siliceous skeletons they would not have been replaced by carbonate of lime in the granular form, but by crystalline calcite. In the few cases where specimens are of crystalline calcite, it is shown that this has replaced a granular condition of the mineral and is not a replacement after silica.

3. *Mode of Growth and Structure of* Archæocyathus *and allied forms.*

These features will be best treated by detailed descriptions, first of *Archæocyathus* proper and then of *Ethmophyllum*, Meek, *Coscinocyathus*, Bornemann, *Anthomorpha*, Bornem., *Protopharetra*, Bornem., and *Spirocyathus*, gen. nov., based on *Archæocyathus atlanticus*, Bill.

Genus ARCHÆOCYATHUS, Billings. (Plate V. figs. 1–6.)

(1861. New Species of Lower Silurian Fossils, p. 3.
1865. Palæozoic Fossils, vol. i. p. 3.)

This genus, of which *A. profundus*, Bill., is taken as the typical species, consists of cup-shaped, subcylindrical, or turbinate forms, apparently free. The outer surface of the wall appears to be generally rugose or with horizontal ridges, sometimes, however, smooth; the inner surface nearly smooth. The basal portion is generally inverted-conical in form; the further growth may be nearly cylindrical with a tubular central cavity; or cup-shaped with a deep hollow, or open saucer-shaped. The wall of the organism consists of an outer and inner lamina or plate, bounding the exterior and the inner surface of the cup respectively, and a series of stout radial vertical septa, which, like those of a coral, extend from the outer to the inner wall-plates (Pl. V. figs. 4, 5.) The wall-plates both of the interior and exterior surfaces are perforate, but in the best-preserved specimen there is a delicate enveloping surface-lamina, which seems to be imperforate. The interseptal loculi are occupied by dissepimental vesicles, like those in many Rugose corals; these are disposed obliquely, with their convexities to the exterior. The

* The specimens of *Ethmophyllum* from Nevada which I have recently received from Mr. Walcott, likewise consist of minutely granular carbonate of lime, which in places has been replaced by calcite. They are imbedded in a matrix of compact reddish limestone. There is thus a singularly close resemblance in the mineral condition of these fossils from the above-mentioned widely separated localities.—(G. J. H., Jan. 24, 1889.)

septa are fairly even in thickness and in their distance apart; new septa are introduced at intervals with the increase in width of the specimen. The septa are perforated by numerous, small, circular or oval apertures, disposed regularly in oblique rows; the dissepiments, however, appear to be imperforate (Pl. V. figs. 4, 5). The walls and septa are of compact, homogeneous limestone; they do not seem to be porous or canalicular; occasionally there are lighter and darker layers, indicating secondary thickenings or layers of material.

The Canadian examples of this genus which I have examined (Pl. V. figs. 1, 2) are all from the so-called Potsdam Limestone of the coast of Labrador; one appears to be the original of the figure of *A. profundus* (Pal. Fossils, vol. i. fig. 2, p. 4). The specimens are all imperfect; they are either weathered and worn on the exterior, or else partly enclosed in the limestone matrix, so that in no case is the natural unworn exterior surface of the fossil exposed. They vary considerably in size; a subcylindrical individual is 37 millim. in height by 20 millim. across at the summit; a cup-shaped specimen of about the same height is 42 millim. wide above, and the wall varies from 4 to 6·5 millim. in thickness; and the surface of a saucer-shaped individual is, in one direction, 60 millim. across, and the wall is from 10 to 15 millim. thick.

The character of the exterior and inner surfaces of the wall in these forms can only be known from sections of specimens which are enclosed in matrix, and even in these the structures are not uniformly preserved, but appear to have been partially destroyed previous to fossilization. In the best of the Canadian examples of *A. profundus* the outer surface of the wall consists of a very thin delicate lamina, apparently non-perforate, and immediately within this is a thin layer of perforate or vesicular tissue. It is only in places that the surface or epithecal lamina has been preserved; where it is present the interspaces in the perforated tissues within are filled with calcite; but where it is wanting the matrix has filled the cavities, showing in this latter case open communication with the interior of the wall. I have not found any trace of a similar epithecal lamina in any of the Sardinian specimens of *Archæocyathus*; but this may perhaps arise from the fact that they are by no means so well preserved as the forms from Canada. The outer surface of the wall in the Sardinian forms consists of an extremely delicate perforate membrane, the pores in which are arranged alternately in vertical rows, of which there are from two to six between a pair of septa; these pores open directly into the interseptal loculi (Pl. V. fig. 6).

In the Canadian specimens the surface of the wall next the cup has also a delicate lamina, like that above described on the exterior, and beneath or within this is a layer of perforated vesicular tissue of varying thickness. In the casts of *Archæocyathus acutus* from Sardinia the inner plate of the wall is directly perforated by closely set circular apertures regularly arranged in quincunx, which open into the cup, and with slight modifications the same structure of the

inner wall is present in the other Sardinian species of this genus described by Dr. Bornemann.

The septa are in immediate connexion with the vesicular tissues of the outer and inner side of the walls. Usually they are distinct and extend quite across the wall, but in some instances they only extend partially across and curve round and unite together (Pl. V. figs. 3, 4). They are apparently simple, thin, cribriform plates; the perforations are about ·2 millim. wide and the rows about ·4 millim. apart (Pl. V. fig. 5). The septa are well developed at a very early stage of growth; in sections of specimens from 2 to 2·5 millim. in diameter there are from 8 to 14 septa; the initial number in another specimen appears to be 12. The number in full-grown individuals seems to be in proportion to their size; thus near the margin of the saucer-shaped specimen above referred to there are 120; in this form they are fairly equidistant from each other, averaging about ·8 millim. apart (Pl. V. fig. 2).

The arched dissepiments connecting the septa laterally fill the interseptal loculi with a vesicular tissue. In some cases the dissepiments show small cloudy spots, probably due to a slight thickening of their substance. They are very irregularly developed even in the same specimen, but this may in part be attributed to the fossilization. They are not present in the Sardinian specimens of *Archæocyathus* which I have seen, nor are they mentioned by Bornemann in connexion with this genus.

In some cup-shaped specimens the wall is apparently of considerable thickness; but this seems to be due to the development of a successive series of calicular walls one within the other, almost after the manner of some forms of *Cyathophyllum* and *Cystiphyllum*.

Archæocyathus, as defined above, occurs in the Lower Cambrian strata (*Olenellus*-zone) at Anse au Loup, Labrador, at Troy *, New York State, probably also in Nevada †, and in various places in the south-west of the Island of Sardinia, whence no fewer than ten species are recorded by Dr. Bornemann ‡.

Genus Ethmophyllum, Meek. (Plate V. fig. 7.)

(1868. American Journal of Science and Arts, ser. 2, vol. xlv. p. 62.)

This genus is based upon specimens from Nevada, of which a preliminary description, without figure, was given by Prof. Meek,

* The *Archæocyathellus* ? *Rensselaericus*, Ford, Am. Journ. Sci. ser. 3, vol. v. p. 211, fig. 1, is not, in my opinion, generically distinct from *Archæocyathus*.

† One of the forms from Nevada included by Mr. Walcott in *Ethmophyllum Whitneyi* seems to me, judging from the figures (Bull. No. 30, pl. iv. fig. 1 *h*), to belong to *Archæocyathus*.

‡ The material at my disposal is insufficient to enable me to discuss the characters of these species. As the Sardinian specimens are all imbedded in a very hard and solid matrix, and can only be studied in sections which it is extremely difficult to orientate, the discrimination of specific characters is rendered very complex, and Dr. Bornemann himself states that the forms to which he has given names cannot in all cases strictly be regarded as definite species. Verstein. Sardiniens, p. 50.

but subsequently, in the belief that the internal structure of the type forms was similar to that of *Archæocyathus profundus*, Bill., he proposed to include them in this latter genus. In 1866, however *, Mr. C. D. Walcott resuscitated the genus and gave a definition of it, much wider in certain respects than can be sustained by the type species, *E. Whitneyi*, so that it also includes other forms, such as *Archæocyathus minganensis*, which are not related thereto. The type form of *Ethmophyllum*, as described by Meek, does, however, possess one feature which serves to mark it off very clearly from *Archæocyathus*, Bill., as defined above. This is the character of the inner lamina of the wall, which instead of communicating with the interior of the cup or tube by simple perforations, consists of a series of relatively large canals directed obliquely upward and inward, so that in transverse section they present the appearance of one or more rows of vesicles cut across (Pl. V. fig. 7). (See also Walcott's figure in Bull. No. 30, pl. iv. fig. 1 *c*.) In the type of *Archæocyathus marianus*, Römer, so carefully described by this author †, the same structural feature occurs; but in this form only a single incomplete row of canals is shown in transverse section of the cup. This species will therefore be included under *Ethmophyllum*.

In the description of *E. Whitneyi* no mention is made of perforations ‡ in the septa, but they are very distinctly shown in the septa of *E. marianum*. Dissepimental tissue is not developed either in the Nevada or in the Spanish form; and in this latter the other structures are so well preserved, that it may be presumed that dissepiments were not originally present. Prof. Meek does, indeed, mention transverse plates in another specimen which he examined; but as the interior cavity of this was likewise occupied by a dense vesicular tissue, it is probable that it belonged either to *Archæocyathus* or *Protopharetra*.

In other respects *Ethmophyllum* approaches closely to *Archæocyathus*, Bill., and its characters may be thus defined:—Funnel-shaped or subcylindrical forms with a finely perforate outer surface; septa well developed; dissepimental tissue apparently wanting; the inner surface of the wall consisting of a series of obliquely directed canals which open into the central cavity.

At present only two species of this genus are known, *E. Whitneyi*, Meek, from the Lower Cambrian (*Olenellus*-zone) of Nevada, and *E. marianum*, F. Römer, from an apparently corresponding horizon near Cazalla, Seville, Spain.

Genus Coscinocyathus, Bornemann.

(1884. Zeitschr. d. deutsch. geol. Gesellsch. p. 704; Versteinerungen Sardiniens, p. 59.)

Turbinate, open saucer-shaped, or subcylindrical forms, resembling

* Bulletin U. S. Geol. Surv. no. 30, p. 75.
† 'Lethæa Palæozoica,' 1ste Lief. (1880), p. 301, fig. 55.
‡ They are not present in the beautifully preserved specimens of this form sent me by Mr. Walcott.

Archæocyathus in the character of the outer and inner wall-plates and of the septa, but possessing in addition transverse cribriform plates, which subdivide the vertical interseptal loculi. These transverse plates, which may be compared to the tabulæ in fossil corals, only that they are perforate, extend quite across the space between the outer and inner laminæ of the wall, but they do not extend into the interior hollow cup. In some cases they are nearly horizontal, in others they are arched or even oblique. In structure they resemble the vertical septa, and in some sections can scarcely be distinguished from them.

Dr. Bornemann has described 15 species of this genus from the Cambrian strata of Sardinia; the differences between them are principally those of size and form and the number of septa and cross-septa or tabulæ. Mr. Walcott * has likewise described a species evidently belonging to this genus, under the name of *Archæocyathus Billingsi* †. It comes from the Lower Cambrian of the Anse au Loup, Labrador.

Genus Anthomorpha, Bornemann.

(1884. Zeitschr. d. deutsch. geol. Gesellsch. p. 705; Versteinerungen Sardiniens, p. 75.)

This genus has been constituted for cup-shaped or turbinate forms with robust vertical septa, dissepiments, and transverse plates or tabulæ. These structures are stated to be non-perforate and thus to form a transition to the true corals.

In the material sent to me by Dr. Bornemann from Sardinia, I have only seen two specimens which could be referred to this genus, and in these the septal walls had been replaced by calcite, so that one could not determine whether they were originally imperforate or not. Only a single species from Sardinia has been referred to this genus by Dr. Bornemann.

Genus Protopharetra, Bornemann. (Plate V. fig. 11.)

(1883. Zeitschr. d. deutsch. geol. Gesellsch. p. 274; id. 1884, pp. 400, 705; Versteinerungen Sardiniens, pp. 38, 39, 46.)

No categorical definition of this genus has been given, for the author did not regard it as an independent organism, but merely the lower or vegetative state of development of forms of *Archæocyathus* and *Coscinocyathus*. Some forms of these genera can be traced, according to the author, to an early stage, in which they exhibit the skeletal structure of *Protopharetra*. In other cases, however, only this *Protopharetra* stage is present, and no connexion with the

* Bull. no. 30, p. 74, pl. iii. figs. 3, 3 *a–c*.

† From an examination of the type of this species (kindly sent me by Mr. Walcott), I believe that the "spicula-like-bodies" referred to in his description are fibres of calcite similar to those described by Bornemann in *Coscinocyathus vesica* and *C. proteus* (Verst. Sardin. p. 71). They are not, in my opinion, sponge-spicules.—(G. J. H., Jan. 24, 1889.)

supposed higher stage of the organism has been discovered; and for such forms, which, in places, Dr. Bornemann states, fill entire beds of rock, the provisional genus *Protopharetra* is proposed. It includes bodies of very varying forms, either cylindrical or growing in extended masses, from which simple or furcated stems are given off. The stems have a tube-like, axial cavity, crossed by tabulæ (*Böden*, Bornem.) and bounded by the porous walls. These consist of a delicate, fibrous, calcareous tissue, of dull, nearly opaque, milk-white aspect in thin sections. The fibres may be cylindrical or flattened, and they anastomose with each other, and thus bear a considerable outward resemblance to the structure of the group of fossil Calcisponges named *Pharetrones* by v. Zittel; but, unlike these, no traces of spicules occur in the fibres, and their minutely granular homogeneous character is opposed to the idea that they originally consisted of spicules.

From microscopic sections of the Sardinian specimens kindly presented to me by Dr. Bornemann I am enabled to confirm the description given by him of the structure of *Protopharetra*. I am not satisfied, however, that these fossils are merely the lower stage of development of *Archæocyathus*-forms. Very small specimens, both of this latter genus and of *Protopharetra*, are present in the same rock-fragments, and the distinctive characters of each are well marked. Fairly large examples of *Protopharetra* also occur, which show no traces of the regular septal structure of *Archæocyathus*.

Five species of this genus have been described by Dr. Bornemann from the Lower Cambrian strata of Sardinia.

Genus SPIROCYATHUS *, gen. nov. (Plate V. figs. 8, 9, 10.)

Generic characters. Infundibuliform or subcylindrical forms, with an axial subcylindrical tube or cavity bounded by thick walls. These are built up of relatively thick, solid, inosculating plates or laminæ, partially connected by delicate fibres, which form a reticulate tissue with irregular lacunæ or canals. The lamina forming the outer surface, and that next the axial tube, are much stouter than those of the central portions of the wall. The outer lamina is apparently perforated by minute apertures, and larger canals connect the interspaces of the wall-tissue with the central cavity. In places the cavity is partially filled up with fibrous outgrowths from the wall. The wall-plates consist of a primary central layer enclosed by successive secondary layers of a minutely granular carbonate of lime.

This genus is based on the type specimen of *Archæocyathus atlanticus*, Bill.† The form had not previously been studied in

* σπεῖρα, a twisted coil, κύαθος, cup.

† New species of Lower Silurian Fossils, 1861, p. 4, figs. 1–3; Pal. Fossils, vol. i. (1865) p. 5, fig. 5. Mr. Walcott (Bull. no. 30, p. 73) regards this species as the type of *Archæocyathus*, Bill.; but I have pointed out already (p. 126, note) that for very good reasons Mr. Billings, in a revised reference to the genus in 1865, distinctly placed *A. profundus* as the type, and that the characters of *A. atlanticus* will not allow of its inclusion in *Archæocyathus*, as defined by Mr. Billings.

microscopic sections, and these show such peculiar structural characters, that they seem to me to justify placing it in a distinct genus. The type specimen is subcylindrical or elongate-conical, the extreme base and summit are wanting, so that the portion preserved is only about 58 millim., or 2⅓ inches in length *, 18 millim. in diameter near the base, and 28 millim. at the top. It has been sectioned transversely near the base, and the upper portion divided by a median longitudinal section. The specimen is in a matrix of hard, compact, reddish limestone, which has been almost entirely removed from the outer surface, but completely fills the interior cavity and also some of the interspaces in the wall; other interspaces are occupied by calcite. The outer surface is apparently smooth, and exhibits obscure annular ridges and wide shallow furrows between them. The walls and substance of the fossil are of limestone of a dull yellowish-white tint; by transmitted light, in thin sections, it shows the same minute granular texture which has been already described in *Archæocyathus*.

The smooth outer lamina of the wall appears to have been perforated by minute, closely-set, subcircular pores, about ·2 millim. in width, giving it a delicately reticulate appearance. This structure can only be distinguished on certain portions of the surface by a strong lens, and it is not shown in transverse sections, possibly because the pores may have been subsequently filled up.

The walls bounding the inner tubular cavity vary from 8 to 10 millim. in thickness, whilst the tube itself is from 10 to 12 millim. wide, or somewhat more than one third the diameter of the fossil. The plates or laminæ composing the wall are very irregularly arranged; sometimes there are traces of a radial disposition (Pl. V. fig. 8), but more frequently they curve and inosculate with each other so as to form a series of closed loops (Pl. V. figs. 9, 10). The outer and inner laminæ, though much thicker, are of precisely the same structure as the intermediate plates. The canals and lacunæ thus enclosed by the wall-plates are very irregular in disposition and size; frequently they are much contracted by the thickening of the plates, and occasionally are quite filled up. The wall-plates are likewise connected by slender calcareous threads, circular in section, and about ·025 millim. in thickness; some of these fibres also irregularly bridge over the axial tube of the fossil and connect opposite sides of the wall.

The primary or central layer of the wall-laminæ is approximately even, about ·12 millim. in thickness; it is distinctly marked off from the secondary layers by marginal lines (Pl. V. fig. 10), but the substance of this layer is of the same nature, though of a lighter tint, by transmitted light than the enclosing secondary layers. These vary in number, but each is more or less distinctly bounded by a marginal line, darker when seen in thin section. The wall-plates vary from ·4 to ·8 millim. in thickness; that bounding the inner tube reaches in places 2 millim. in thickness, from the depo-

* In the Pal. Foss. vol. i. p. 6, the fragment is stated to be 4½ in. in length, but this seems to be a mistake.

sition of numerous secondary layers on its inner side. Owing to the infilling of the axial tube by the solid matrix, the characters of the inner surface of the wall can only be seen in the sections; it appears to be uneven, with projecting points and ridges, and to be penetrated by wide canals.

In one portion of the central tube of the type specimen a section of a small individual, 2 millim. in diameter *, is exposed, which may be of the nature of a bud, though its connexion with the larger specimen is not definitely shown.

The character and arrangement of the structures in the wall of *Spirocyathus* definitely mark it off from *Archæocyathus* and the allied genera in which there are distinct radial vertical septa. In general characters† *Spirocyathus* approaches *Protopharetra*, Bornem., the principal differences being the peculiar primary and secondary layers in the wall-plates and the absence of tabulæ (*Böden*); further it is a simple form.

The only species at present known is *Spirocyathus atlanticus*, Bill., sp., from the lowest fossiliferous or *Olenellus*-zone of the Cambrian at Anse au Loup, Labrador. It is also present at the corresponding horizon in Nevada, as shown by Mr. Walcott ‡.

4. *Affinities of* Archæocyathus *and allied forms.*

The genera *Archæocyathus*, Bill., *Coscinocyathus*, Bornem., *Anthomorpha*, Bornem., and the provisional genus *Protopharetra*, Bornem., were included by Dr. Bornemann § as a separate group of the Cœlenterata under the name of the Archæocyathinæ. In the same group may now be reckoned *Ethmophyllum*, Meek, and *Spirocyathus*, gen. nov. Of these genera, *Protopharetra* and *Spirocyathus* are closely related together, and differ from the others in the absence of distinct radial septa and some other features; but in their minute structure and their general plan of growth they are similar, and may be regarded as belonging to the same group, the zoological relations of which we now propose to consider.

First, as regards their relationship to Sponges, with which they

* Mr. Walcott seems to have been the first to call attention to this young specimen. See Bull. no. 30, p. 73.

† I have felt considerable difficulty in determining whether *Spirocyathus* could be established as a genus distinct from *Protopharetra*, Bornem.; for though I have not seen in the specimens sent me from Sardinia the peculiar characters of the wall-plates so conspicuous in the former genus, it is just possible that these features might have been lost in the fossilization of the Sardinian forms of *Protopharetra*. I have also felt the further objection to merging *Spirocyathus atlanticus* under *Protopharetra*, since Dr. Bornemann has expressly stated (Verstein. Sardiniens, pp. 47, 48) that this latter does not indicate an independent genus; whereas, whatever may be the case with the Sardinian forms, I can entertain no doubt that the type of *Spirocyathus* is of itself quite independent of *Archæocyathus*.

‡ Bull. no. 30, pl. iii. figs. 1 *b*, 2, 2 *a*.

§ Zeitschr. d. deutsch. geol. Gesellsch. 1884, p. 706; Versteinerungen Sardiniens, p. 28.

were, by Mr. Billings*, ultimately classed, owing to his unfortunate mistake in regarding *Arch. profundus* and *Arch.* (now *Spirocyathus*) *atlanticus* as structurally similar to the *A. minganensis*, which is a true siliceous sponge. We have seen that in all the forms above mentioned the skeleton is composed of carbonate of lime in a minutely granular condition, and there is every indication that this is the original material, and that it is not a replacement after silica, so that any relationship to siliceous sponges is altogether excluded. As regards their probable alliance to Calcisponges, there are no known forms of this group, whether fossil or recent, with the same regular septate build of the skeleton which distinguishes most of the genera of the Archæocyathinæ. *Spirocyathus* and *Protopharetra* do, indeed, in the reticulate and partly fibrous character of their skeletons, bear an outward resemblance to the fossil Pharetrones †, and it has been suggested that, as in many of these sponges, the fibrous structures may have originally consisted of spicules which have been destroyed in the fossilization; but to this supposition may be opposed the fact that the fibres of true Pharetrones whose spicular structures have been destroyed do not show the same minute granular condition which is present both in the Sardinian and Canadian examples of the two above-named genera, and, further, in no example of Pharetrones which has come under my observation is there, in the skeleton-fibres, a primary layer enclosed by successive secondary layers, which is so clearly shown in *Spirocyathus*. This feature is, in my opinion, conclusively opposed to the idea that the skeleton of this genus, like that of the Pharetrones, consisted originally of spicules of carbonate of lime.

Next, as to the relations of the Archæocyathinæ to Foraminifera, with which group *Archæocyathus* has been compared by Sir J. W. Dawson ‡. The general form and structure of this organism does not bear any close resemblance to any known fossil or recent genus of Foraminifera, and the septal interloculi crossed by dissepiments cannot be compared with the chamber-system of Foraminifera.

Archæocyathus has been included in the Receptaculitidæ by Prof. Ferd. Römer on the grounds of possessing a perforated outer and inner wall, enclosing a central cavity as in *Receptaculites*. The resemblance, however, is of too slight a character and insufficient to indicate any close relationship, particularly if the real nature of the skeleton of this latter genus is taken into consideration.

We may now consider the probable relationship of the Archæocyathinæ to Corals, with which they were at first compared both by

* Pal. Foss. vol. i. p. 357.

† Versteinerungen Sardiniens, p. 37.

‡ Can. Nat. and Geologist, 1865, p. 103, note; Pal. Foss. vol. i. p. 356; Dawn of Life (1875), pp. 151–155. Mention is here made of a canal-system within some of the thicker plates of *Arch. profundus*; but the original section from which fig. 41 *c*, p. 154, was taken shows that the supposed canals are merely accidental defects in the preparation of the section.

Billings * and Meek †; Dr. Bornemann ‡ and Prof. Meneghini § also for some time regarded the Sardinian examples of *Archæocyathus* as species of *Cyathophyllum*. Their form and mode of growth so precisely simulate turbinate or subcylindrical specimens of Silurian and Devonian genera of Rugose Corals, that they would at once be regarded as such by any one at all familiar with these organisms, and, indeed, in some weathered-out specimens of *Archæocyathus* the differences are not apparent until sections have been made.

The radiate vertical septa in *Archæocyathus* and its allies may strictly be compared with the same structures in corals; they commence from the outer surface-wall of the organism, with which they are in immediate connexion, and extend to the lamina bounding the inner tube or cup, which, indeed, is formed in some cases by the lateral extension and union of proximate septa. In their perforate character, as has already been pointed out by Mr. Billings, the septa resemble those of perforate corals, which, however, are of rare occurrence in Palæozoic strata; but since Mr. Billings wrote, a genus of corals ||, *Calostylis*, Lindstr., has been discovered in the Silurian strata of the Isle of Gotland, in which the septa are markedly perforate, like those of *Archæocyathus*.

The regular perforate character of the outer surface of the wall, so clearly shown in some of the Sardinian specimens of *Archæocyathus* and in *Ethmophyllum marianum*, Röm., and *E. Whitneyi*, from Spain and Nevada respectively, cannot find a parallel in any palæozoic coral with which I am acquainted; but some tertiary fossil and recent deep-sea forms (such as, for example, *Stephanophyllia formosissima* ¶, Moseley) have their basal surface perforated in a manner equally delicate as in the Cambrian Archæocyathinæ. It is probable that there may have been in *Archæocyathus profundus* an outer delicate imperforate lamina of an epithecal character, the same as in the majority of corals.

The dissepiments connecting the septa in *Archæocyathus* and in some of the allied genera bear a close resemblance to the same structures in many Rugose Corals, such as *Cyathophyllum* and *Cystiphyllum*. The tabulæ in *Coscinocyathus*, though comparable in position to those of Rugose Corals, differ in their perforate character.

In the well-developed perforated laminæ of the wall bounding the inner tube or cup, *Archæocyathus* and some of the allied genera differ from more recent corals, and the peculiar oblique canals which characterize the genus *Ethmophyllum* are also without a counterpart in other corals. In the genus *Anthomorpha*, Bornem.,

* New Species of Lower Sil. Fossils, 1861, p. 3.

† Amer. Journ. Sci. and Arts, vol. xliv. 1868, p. 62.

‡ Extrait du Compte Rendu du Congrès géol. intern. à Bologne (1881), p. 3.

§ Atti della Società Toscana di Sc. Nat. (1881), p. 201.

|| Öfversigt k. Vetenskaps-Akad. Förhandl. 1868, p. 421. The same genus has been found by Nicholson and Etheridge in Scotland. See Mon. Girvan Fossils, fasc. 1, p. 65, pl. v. figs. 2, 2*c*. It also occurs in the Wenlock district.

¶ Report on 'Challenger' Corals, p. 201, pl. xiii.

however, there is, judging from Dr. Bornemann's descriptions and figures, a much closer resemblance to Rugose Corals than in the other genera of the family ; for the septa and wall-plates are imperforate, and there is not a well-defined inner wall to the cup or tube, the central portion of which is filled by vesicular tissue.

In the non-septate or obscurely septate genera, *Protopharetra* and *Spirocyathus*, the resemblance to corals is far less striking ; but the reticulate disposition of the laminæ of the wall in these forms bears a singularly close correspondence to that in the outer zone of the wall in *Calostylis*, Lindstr., and other later perforate corals. In these latter the outer reticulate zone passes into an inner septate zone, whereas in the former genera the reticulate disposition remains, as a rule, throughout the entire thickness of the wall, though occasionally traces of radiate septa are developed. The thickening of the wall-plates in *Spirocyathus* by a secondary deposition of successive layers of material may also be compared to the successive layers of stereoplasm in many other corals, both fossil and recent.

Owing to the many changes induced by fossilization, a comparison of the minute structure of the wall-plates in the Archæocyathinæ with that in other fossil corals is not of special value ; but it may be noted that the minutely granular carbonate of lime of which the walls in this group now consist is likewise of common occurrence in fossil corals, though apparently in the older fossils it is somewhat more dense and opaque in thin sections.

The above considerations appear to me to indicate that the Archæocyathinæ belong to a special family of the *Zoantharia sclerodermata*, with near relationship (leaving *Anthomorpha* out of account) to the *Perforata*. An objection may be taken to the above view from a geological standpoint, since other undoubted corals have not hitherto been discovered in Cambrian strata, and it is not till reaching the Ordovician that they have made their appearance, and, if we except *Calostylis*, perforate corals (comparable to *Archæocyathus*) are hardly met with in Palæozoic strata. On this objection, however, little weight can be laid ; for though it is remarkable to find organisms with such a general correspondence to perforate corals in the lowest fossiliferous Cambrian strata, yet they are in association with Trilobites and other fossils of a higher grade in the scale of organized life, and there can be little doubt that the existence of coral life dates back to a period long anterior to the deposition of the Cambrian limestones.

5. *On* Archæoscyphia, *gen. nov.*, Calathium, *Bill.*, Trichospongia, *Bill., and* Nipterella, *gen. nov.*

It has been already mentioned that one species included by Mr. Billings in the genus *Archæocyathus* (*A. minganensis*) proves to be a siliceous sponge, and that the same author compared the genus itself with *Calathium*, Bill., and with other sponges. The Geological Survey of Canada, through Mr. J. F. Whiteaves, F.G.S., has enabled me to study the type forms of *A. minganensis* and of

the other genera with which it is associated; and it seems desirable, by describing the microscopic structure of these forms, to show their real characters, and at the same time the radical differences between them and *Archæocyathus* proper and its allied genera. I have likewise been permitted by the Director-General of the Geological Survey of Great Britain to examine some fossils from the Durness Limestones of the north-west of Scotland, which had been referred to *Archæocyathus*; and their minute structure proves that they are not related to the true genus of this name, though they are to *Archæoscyphia minganensis* and *Calathium*.

Genus ARCHÆOSCYPHIA, gen. nov. (Plate V. figs. 12, 13, 14.)

This genus is proposed to include *Archæocyathus minganensis* with the following generic characters:—

Sponges simple, vasiform or subcylindrical, apparently free. Outer surface with strongly marked annular projections. Wall robust, the skeleton built up in the form of septum-like longitudinal plates, closely arranged with narrow interrupted spaces between. The dermal layer smooth, with minute canal apertures, beneath are larger canals opening into the intervals between the septum-like plates. No definite inner wall next the cloacal cavity. The skeleton consists of minute siliceous spicules of the tetracladine type; their rays are slightly furcate and branched at their extremities, and they interlock without forming prominent nodes. In many spicules only three rays are apparently developed. Irregular branching spicules are likewise present.

At present only fragments of the type species are known, from which Mr. Billings produced a restored figure of the complete sponge, which has been often copied in different works. The fragments indicate a specimen of at least 80 millim. in height and 50 millim. in width. They are wholly siliceous, in a somewhat granular condition, and very unfavourable for preparing sections. The original structure of the interior has almost entirely been obliterated in the fossilization, so that only indistinct traces of the spicular mesh can be recognized in thin sections. The form of the sponge is peculiar, from the irregular annular extensions or platforms developed at intervals on the outer surface, which in places project from 10 to 15 millim. beyond the general surface of the wall (Pl. V. fig. 12). In the intervals between these rings the wall is about 6 millim. in thickness. The septum-like plates are from ·5 to 1 millim. in thickness, with about the same distance between each. Their connexion with the outer portion of the wall is by no means so distinct as it appears in Mr. Billings's figures, and the interspaces are now to a great extent infilled by siliceous material, but they appear originally to have been bridged over by lateral extensions of the skeletal mesh. The inner edges of the septum-like plates are free and uncovered, and I can see no traces, in the type specimens sent to me, of an inner wall (Pl. V. fig. 13).

The dermal layer is smooth; very minute perforations can be seen

in it in places, but no distinct spicules. Where the smooth surface-layer has been worn away, small canal-apertures, about ·5 millim. wide, are exposed (Pl. V. fig. 12). It is only in certain weathered places on the outer surface of the sponge that the spicular structure can be clearly seen. The spicules are very small, the rays vary from ·1 to ·2 millim. in length, and about ·03 millim. in thickness. They appear to have been united together by the intertwining of the branching extremities of the rays, but no prominent nodes are formed by the junction as in the majority of the Mesozoic tetracladine sponges. In most of the spicules only three rays can be distinguished, but in some the normal four rays are developed (Pl. V. fig. 14). The irregular spicules consist of a single straight or curved axis, with branching ends. That the entire sponge was built up of similar spicules to those on the surface, is proved by the traces of them in thin sections of the interior of the wall.

The peculiar form of the outer surface and the strongly marked septum-like disposition of the spicular skeleton readily distinguish this genus from other fossil and recent Lithistids. This septum-like arrangement, however, is not peculiar to *Archæoscyphia*, since it is present, though in a less marked degree, in the Mesozoic genera *Cnemidiastrum*, Zitt., and *Corallidium*, Zitt.

Archæoscyphia minganensis was first described by Mr. Billings * as the cast of the interior of a coral belonging to the genus *Petraia*. In 1861 this author † included it in *Archæocyathus*, and stated that it occurred in the Calciferous Formation of the Mingan Islands, and also in the Potsdam Limestone of Anse au Loup, Labrador. In 1865 ‡, however, the Potsdam specimens were regarded as distinct, and the specific name was restricted to the specimens from the Mingan Islands. In these Mr. Billings discovered numerous rod-like spicules which were regarded as adventitious, and branching spicules belonging to the organism itself. Mr. Billings then described it, and rightly, as a sponge, but he retained it still in *Archæocyathus*, though beyond a rude correspondence in form there is nothing in common between *A. minganensis* and *A. profundus*, the type of *Archæocyathus*. In the former of these the skeleton is siliceous and consists of spicules; in the latter it is compact carbonate of lime, and there are no traces whatever of spicules.

Only a single species of this genus, *A. minganensis*, Bill., sp., has been definitely recognized from the Calciferous Formation of the Mingan Islands, Lower St. Lawrence. In the Durness Limestones of Sutherlandshire some weathered-out siliceous sponges occur, which, so far as their imperfect state of preservation allows of comparison, appear to belong to *Archæoscyphia*, and possibly to a species distinct from *A. minganensis*.

* Canadian Nat. and Geol. vol. iv. 1859, p. 346.
† New Species of Lower Silurian Fossils, 1861, p. 5.
‡ Pal. Foss. vol. i. pp. 5, 354.

Genus Calathium, Billings.

(1865. Pal. Fossils, vol. i. pp. 208, 209.)

Sponges inverted conical or subcylindrical, with large cloacal cavity. The walls perforated by closely-set, circular, or oval canal-apertures, disposed so as to form nearly horizontal and longitudinally spiral lines. Spicular structure unknown.

This genus is based on *Calathium formosum*, Bill.*; the type specimen is inverted conical, 46 millim. in height and 24 millim. in width at the summit. The outer surface is quite weathered out of the rock, but the interior is solidly filled with a dark limestone matrix. The canal-apertures of the wall are about 1 millim. in diameter, and from ·5 to 1 millim. apart. The walls are not more than 3 or 4 millim. in thickness; though siliceous, their spicular structure has been entirely obliterated, so that whether it is hexactinellid or lithistid cannot be known from the type specimen. This is from the Calciferous Formation (Division G of Billings) at Cape Norman, Newfoundland †.

Calathium Anstedi, Billings.

1865. *C. Anstedi*, Bill. Pal. Foss. vol. i. p. 210, fig. 194.

A fragmentary specimen from the Durness Limestone of Sutherlandshire agrees so closely with Billings's description and figure of this species that it may safely be included under it. The fragment is the upper portion of a turbinate specimen; the walls are 8 millim. in thickness, and the cloacal cavity 50 millim. in width. The canal-apertures of the surface are in nearly horizontal and vertical rows; they are smaller than in *C. formosum*, being about 4 in 5 millim. No traces of the spicular structure remain. The form described by Mr. Billings is from the Calciferous Formation (Division H), Pistolet Bay, Schooner Island, Newfoundland.

Genus Nipterella ‡, gen. nov. (Plate V. fig. 15.)

I propose this genus to include *Calathium* (?) *paradoxicum* §, Billings, with the following generic characters:—Sponges massive, subcylindrical, with basal expansion; summit truncate, with an open, shallow, basin-like depression. Traces of canals extending from the surface to the interior. Skeleton, a close meshwork of lithistid spicules. Spicules rod-like, with branching or truncate ends.

The type specimen, which is now of solid silica, is subcylindrical, about 50 millim. in height by 60 millim. in width, with an uneven expanded base ||. The basin-like hollow at the summit is not more

* Pal. Foss. vol. i. p. 209, fig. 192.

† *Ibid.* vol. i. p. 371.

‡ νιπτήρ, a laver, dimin.

§ Pal. Foss. vol. i. p. 358, fig. 345.

|| In the figure given by Mr. Billings the sponge is, in my opinion, represented upside down.

than 10 millim. in depth. The outer surface is rough and uneven, showing no other structure beyond traces of infilled canals apparently directed towards the summit. Minute radial canals can be faintly seen in some places in the interior of the wall. The body of the sponge appears to have been entirely filled with the skeletal tissue, but the spicules are now to a great extent obliterated; they are variable in form, but chiefly with a straight or curved axial portion, and tuberculated and slightly branched extremities, thus of the *Rhizomorina*-type (Pl. V. fig. 15).

The general build of this sponge is clearly distinct from that of the genus *Calathium*, in which Mr. Billings provisionally placed it.

The type species is from the Calciferous Formation of the Mingan Islands, Lower St. Lawrence.

Genus Trichospongia, Billings.

(1865. Pal. Foss. vol. i. p. 357.)

This genus occurs in depressed cup-shaped masses, now of granular silica, in which the original structure is largely destroyed. Partially detached rod-shaped or acerate spicules are present in the porous portion of the mass, and traces of similar spicules in thin sections of the more compact portions. Some of the spicules have apparently a subparallel arrangement, but no definite fibres can be made out. As no other than monactinellid spicules are present, the genus may be regarded as belonging to the suborder Monactinellidæ. Only one species, *T. sericea*, Bill., is known, it is from the Calciferous Formation of the Mingan Islands.

It is worthy of remark that the Calciferous Formation of the Mingan Islands is the lowest geological horizon in which sponges are met with in sufficient numbers to constitute an appreciable element in the fossil fauna. Below this horizon only the hexactinellid genus *Protospongia* is known, and specimens of this are of comparatively rare occurrence. In the Mingan strata two genera of Lithistid sponges, *Archæoscyphia* and *Nipterella*, are the earliest known representatives of this important group, whilst *Trichospongia* is the earliest Monactinellid genus yet described; and, judging from the variety of detached acuate and acerate spicules in the same rocks *, other forms of the same group are associated with it. Another genus, *Rhabdaria*, is likewise mentioned by Mr. Billings †; but the spicular structure of this is not yet known. It is also noticeable that the presence of siliceous sponges in these rocks is associated with the occurrence in them of many nodules and patches of chert ‡; also in the Durness Limestones, in which *Archæoscyphia* and *Calathium* have been recognized, and other siliceous

* Billings, Pal. Foss. vol. i. p. 355, fig. 344; Hinde, Geol. Mag. vol. v. (1888), p. 226, fig. 1, *a–d*.

† Pal. Foss. vol. i. p. 357.

‡ Geological Survey of Canada, Report of Progress, 1863, p. 120.

sponges occur, though too poorly preserved for generic determination, large masses of chert have lately been described *, thus indicating in the Cambrian strata the same relation of the chert to the presence of sponge-life which has already been pointed out by the writer in the Upper Carboniferous (Yoredale) Beds of Ireland † and in rocks of later date.

Summary.

A revision of the type specimens of the three species included by Mr. Billings in the genus *Archæocyathus* shows that each of the species represents a distinct genus. *Archæocyathus profundus*, having been selected by Mr. Billings in 1865 as the typical species, is retained as such, and the characters of the genus, as shown in this species, are redefined. *Archæocyathus atlanticus*, Billings, is made the type of a new genus, *Spirocyathus*; and the third species, *Archæocyathus minganensis*, proves to be a siliceous sponge, and is included in a new genus, *Archæoscyphia*.

Including the genera allied to *Archæocyathus*, described by Meek and Bornemann, the following constitute the family *Archæocyathinæ*, proposed by this last-named author:—*Archæocyathus*, Bill.; *Ethmophyllum*, Meek; *Coscinocyathus*, Bornem.; *Anthomorpha*, Bornem.; *Protopharetra*, Bornem.; and *Spirocyathus*, g. n.

The genera of this family are characterized for the most part by turbinate or subcylindrical forms with stout walls, including an interior tubular or cup-shaped cavity. Their skeletons are of carbonate of lime in a minutely granular condition. The walls in the first four of the above-named genera consist of an outer and an inner lamina connected by vertical radial septa; dissepiments are generally present between the septa; save in the genus *Anthomorpha*, the outer lamina of the wall is regularly and minutely perforate, and the inner lamina and septa are likewise cribriform; *Ethmophyllum* is particularly distinguished by oblique canals connecting the interspaces of the wall with the central cavity; *Coscinocyathus* by transverse perforate tabulæ; and *Anthomorpha* by the apparently imperforate character of the surface-laminæ and septa. *Protopharetra* and *Spirocyathus* are not distinctly septate, but their skeletons consist of irregularly curved anastomosing laminæ and fibres; in the latter genus the laminæ are remarkably thickened by successive secondary deposits of calcareous material.

The Archæocyathinæ are regarded as a special family of the *Zoantharia sclerodermata*, in some features allied to the group of perforate Corals. The family is restricted, so far as known at present, to the lowest fossiliferous zone of the Cambrian strata, that characterized by the trilobitic genus *Olenellus*, Hall, and it occurs at Anse au Loup, Labrador; Troy, New York State; Nevada; Sierra Morena, Spain; and in the south-west of the Island of Sardinia.

* "Recent work of the Geol. Survey in the N.W. Highlands of Scotland," Quart. Journ. Geol. Soc. vol. xliv. 1888, pp. 404, 406, 407.

† Geol. Mag. vol. iv. 1887, p. 435; *ib.* vol. v. 1858; Phil. Trans. 1885, pt. ii. pp. 403–453.

The genus *Archæoscyphia*, based on *Archæocyathus minganensis*, Bill., is shown to be a Lithistid sponge; and *Nipterella*, n. g., based on *Calathium* (?) *paradoxicum* belongs likewise to the same group of sponges. The genera *Calathium*, Bill., and *Trichospongia*, Bill., are also undoubted siliceous sponges. These various sponges, which were either included in *Archæocyathus* by Billings or regarded as allied thereto, have no relation whatever to this genus or to any member of the family in which it is included. They likewise come from a distinctly higher geological horizon, that of the Calciferous Formation of the Canadian geologists, which is probably at the summit of the Cambrian system. They are found in this formation in the Mingan Islands, Lower St. Lawrence, and in Newfoundland: species of *Archæoscyphia* and *Calathium* are also present in the Durness Limestones of the North-west of Scotland, but I have not seen any undoubted examples of *Archæocyathus* associated with them.

EXPLANATION OF PLATE V.

Fig. 1. *Archæocyathus profundus*, Bill. A specimen showing the outer form and traces of the septa; the surface has been weathered. Natural size. From the Cambrian strata at Anse au Loup, Labrador. The specimen belongs to the Museum of McGill College, Montreal.

Fig. 2. *The same.* A saucer-shaped specimen, viewed from above. The radiating septa and dissepiments now appear as depressed lines in the matrix. Natural size. Also from Anse au Loup, Labrador. The specimen belongs to the Collection of the Geological Survey of Canada, Ottawa.

Fig. 3. *The same.* Portion of a transverse section of a specimen drawn from a microscopic section, and enlarged four diameters. The immediate outer surface is not preserved; the vesicular tissue next the central cavity is largely developed. The specimen is from Anse au Loup, and belongs to the Geological Survey of Canada.

Fig. 4. *The same.* A fragment of the transverse section of a cup-shaped specimen, enlarged ten diameters, showing below a slight development of vesicular tissue and a definite inner lamina of the wall. The section belongs to the Geological Survey of Canada.

Fig. 5. *The same.* Portion of a longitudinal section of the wall of the same specimen, showing in places the perforations in the septa and the dissepiments. Enlarged five diameters. From Anse au Loup, Labrador. The specimen belongs to the Geological Survey of Canada.

Fig. 6. *Archæocyathus ichnusæ*, Meneghini. A portion of the outer surface of the wall, showing the minute perforations between the septa. Enlarged forty diameters. From Cambrian strata at Punta Pintau, Sardinia.

Fig. 7. *Ethmophyllum Whitneyi*, Meek. Portion of a microscopic transverse section of a specimen, enlarged ten diameters, showing the septa and the oblique inner canals of the wall in section. From the Cambrian strata of Nevada. [This figure has been introduced since the paper was read before the Society.]

Fig. 8. *Spirocyathus atlanticus*, Bill., sp. Portion of a transverse section, enlarged four diameters, showing the arrangement of the laminæ of the wall; for the most part irregular, but apparently radial in some places. From the type form belonging to the Geological Survey of Canada.

Fig. 9. *The same.* Portion of a longitudinal section of the wall of the type specimen, from Anse au Loup, Labrador. Enlarged four diameters. It belongs to the Geological Survey of Canada.

Fig. 10. *The same.* A portion of a transverse section from the type specimen, enlarged ten diameters, showing the characters of the primary and supplementary layers of the wall-laminæ.

Fig. 11. *Protopharetra*, sp. A transverse section of a small specimen, enlarged ten diameters. From Cambrian strata at Canal Grande, Sardinia.

Fig. 12. *Archæoscyphia minganensis*, Bill., sp. A fragment of the type specimen, showing portions of two of the annular platforms and the canal-apertures of the outer surface of the wall. Natural size. From the Calciferous formation of the Mingan Islands, Lower St. Lawrence. The specimen belongs to the Geological Survey of Canada.

Fig. 13. *The same.* A portion of the inner surface of the same fragment, showing the inner edges of the longitudinal plates of the skeleton. Natural size.

Fig. 14. *The same.* Spicules of the sponge, weathered out on the surface. Enlarged sixty diameters.

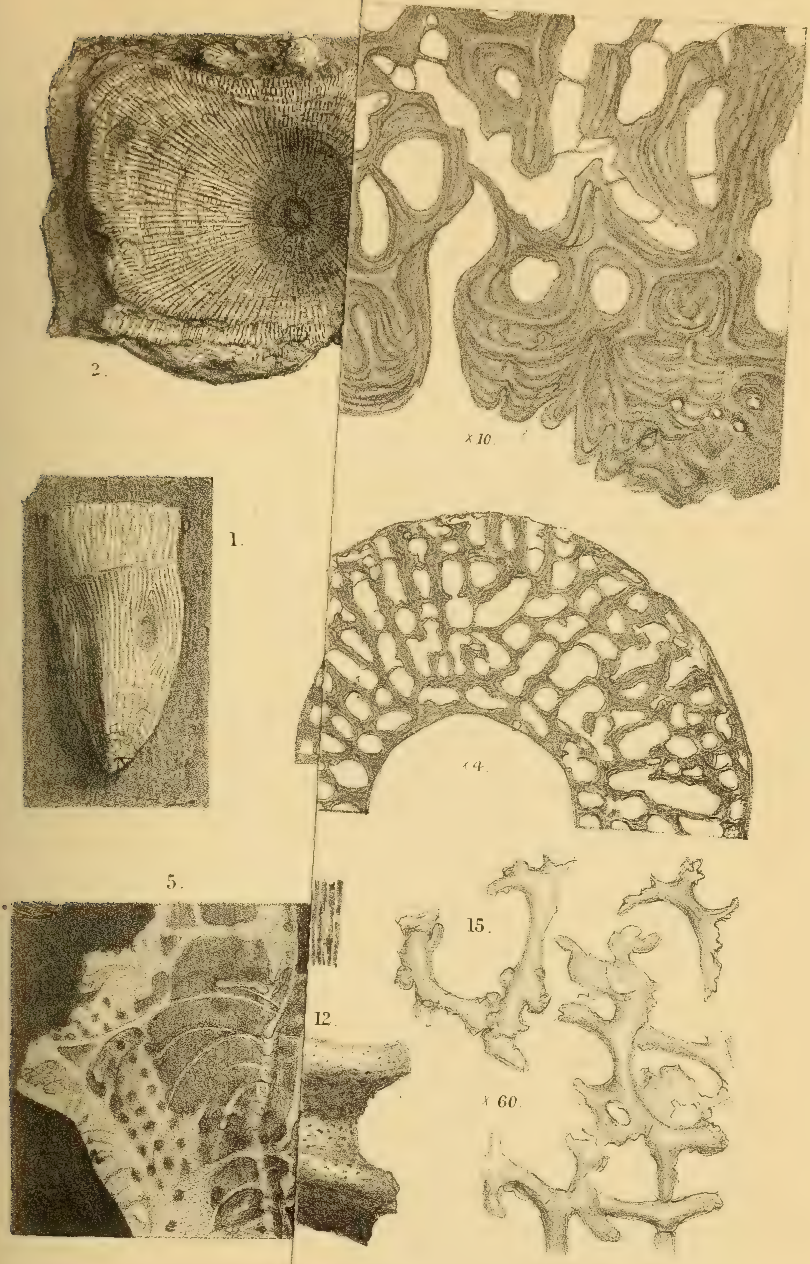
Fig. 15. *Nipterella paradoxica*, Bill., sp. Spicules of the sponge shown in microscopic sections of the interior. Enlarged sixty diameters. From the Calciferous Formation of the Mingan Islands.

Discussion.

The President, after remarking that the Author had thrown much light on an obscure subject, observed that the paper was beyond the criticism of all who had not devoted especial study to sponges and corals. The Society could only thank Dr. Hinde for his able descriptions. It was satisfactory to have so difficult a group cleared up in such a manner, and interesting to find that even in these very old rocks there were no forms intermediate between corals and sponges, though the corals might be less differentiated than those of later periods.

Mr. E. T. Newton paid a tribute to the readiness Dr. Hinde had shown in affording assistance in deciphering certain Durness fossils. One of the most obscure of these, which had somewhat the appearance of a Ventriculite, had been determined by Dr. Hinde to be a siliceous sponge, but he wished to know if the Author had seen spicules in the Scotch specimens.

The Author had not found spicules in the Scotch specimens themselves; but they occurred in the same rock. He thanked the meeting for the way they had received his paper.



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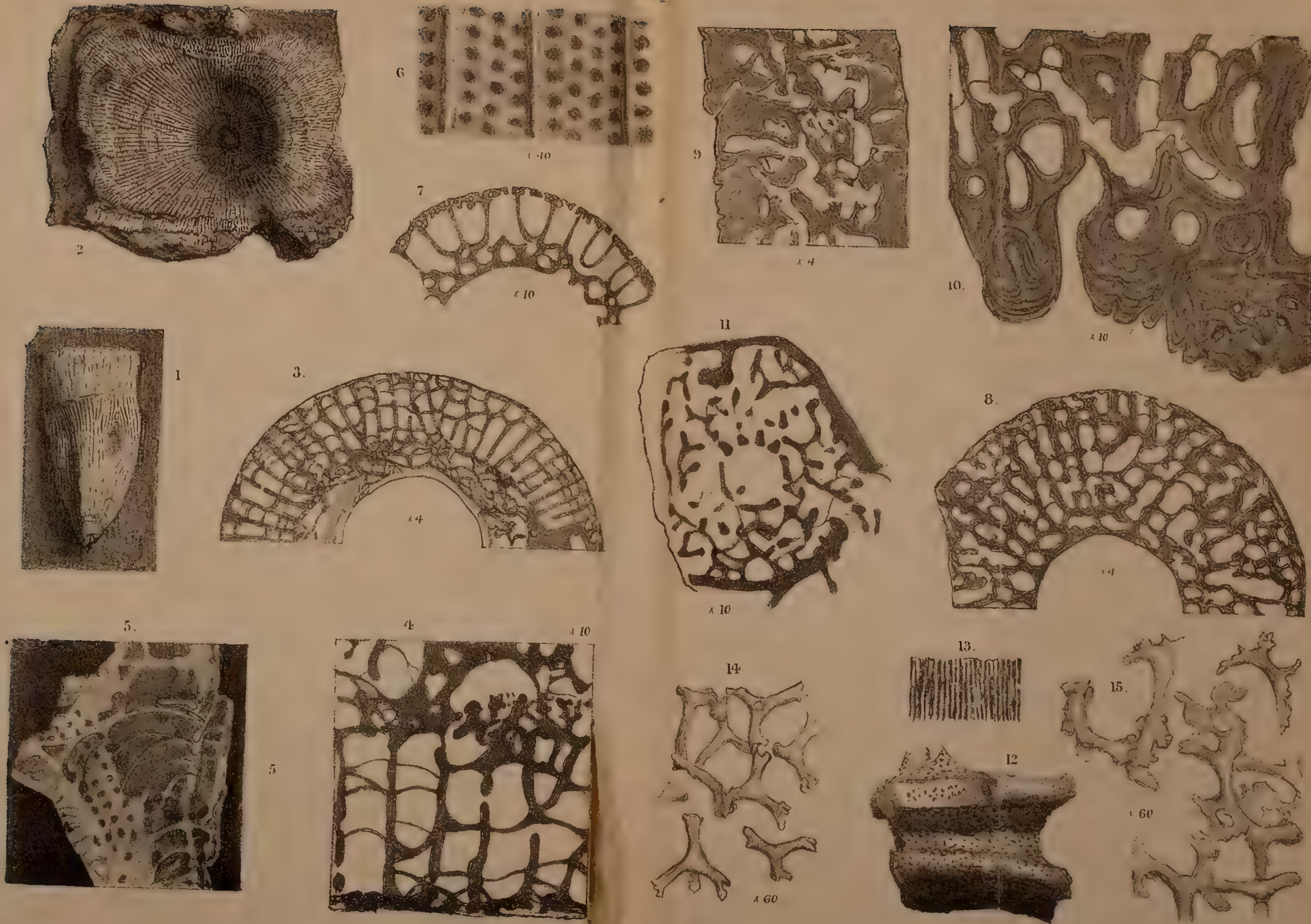

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CAMBRIAN ARCHÆOCYATHINÆ & SPONGES.

9. Trigonocrinus, *a new* Genus *of* Crinoidea, *from the* "Weisser Jura" *of* Bavaria; *with the Description of a* new Species, T. liratus.—Appendix. Sudden Deviations *from* Normal Symmetry *in* Neocrinoidea. By F. A. Bather, Esq., B.A., F.G.S., of the British Museum (Natural History). (Read December 19, 1888.)

[Plate VI.]

Locality and Horizon.

The National Collection contains a large amount of material from the White Jura of Würtemberg and Bavaria. The exact horizon and locality of the specimens is often doubtful. Several hundred calyces of *Eugeniacrinus*, chiefly *E. caryophyllatus*, together with some thousand stem-fragments of the same genus, are said to come from Streitberg, which is a locality for Upper Oxfordian fossils in the district of Ober Franken. In sorting this abundant material the two specimens that I now propose to describe were found. The remains in question consist of calcspar tinged a dirty yellow; they appear to have been washed out of a yellowish marly matrix. They probably occurred in the same bed as the *Eugeniacrini*; and, after a comparison with fossils in continental museums, I am inclined to refer them to the "Weisser Jura *a*." It is greatly to be regretted that no more certain evidence is available.

Description of the Specimens.

Imagine an amphora of triangular section, with an "ear" at each corner in the shape of a spine, the mouth fairly broad, the bottom broken off, and the whole only 4 mm. high. Such gives a fair idea of these singular fossils. It will be convenient to distinguish the two specimens as A and B.

Specimen A is the more perfect of the two, especially at the lower or aboral end.

There is no trace of a *Stem* in the specimen, nor are there obvious signs of a sutural surface on the aboral ends of the basals; the large size, however, of the aperture at the base of the calycal cavity (Pl. VI. fig. 4), though it need not have corresponded to a large axial canal, seems to prove the presence of at least some stem in the living animal.

The *Basals* are four in number and are of three sizes. The largest is but very little stouter than the two next it in size; the second and third are equal to one another, and lie one on each side of the largest; the fourth, or smallest, is extremely minute and cannot be distinguished by the naked eye. These basals are anchylosed into a solid ring, which, looked at from below (Pl. VI. fig. 4), forms an almost equilateral triangle; the largest basal lies at the apex, the second and third basals at the other angles, while the smallest basal lies between the second and third in the middle

of the base-line. The presence of this small basal makes the base of the triangle very slightly longer than the two other sides, but does not otherwise affect the regularity of the figure; in fact this smallest basal is quite invisible when the calyx is viewed directly from below. The sides of this triangle are not straight, but sinuous, with a depression on either side of a median swelling. The large basal aperture of the calycal cavity forms a circle inscribed within the triangle. The diameter of this circle is about 1 mm.; the thickness of the basal triangle at the middle of each side is about ·2 mm.; the thickness of the basal triangle at the angles is about ·5 mm. Each of the three larger basals therefore, as seen from below, forms a triangle with concave base, and sides concave in the lower third, convex in the upper two thirds. As seen from the side (Pl. VI. fig. 7) the largest basal is of irregular hexagonal outline, and is bisected by a ridge running vertically between its extreme adoral and aboral angles: the aboral angle is obtuse, the adoral angle is very little less than a right angle; the sides containing these two angles are of nearly equal length, and are clearly defined by the basi-radial sutures above, and by the free aboral margin of the basal below: the two other sides of the hexagon, representing interbasal sutures now invisible, are relatively short, about ·25 mm. The two basals next in size, as seen from the side, are pentagonal (Pl. VI. fig. 7); they differ from the largest basal in the less-marked character of the vertical median ridge, and in the absence of an aboral angle: each joins on to the largest basal by one side, while by the other sides they join one another: the sutures have disappeared, but their former position is indicated by three slight depressions on the edge between the aboral and lateral surfaces of the basal ring. The smallest basal (Pl. VI. figs. 2 & 7) is a mere tubercle lying between the second and third basals, and forming at this point a minute adoral angle, which resembles, in everything except size, the adoral angles of the other basals. The outer lateral surface of these basals is ornamented with minute granules, irregularly arranged.

The *Radials* are four in number and are of two sizes. They rest between the adoral angles of the four basals, and their lower ends are gently curved. The two radials on either side of the largest basal (Pl. VI. fig. 1) are broader than the other two and in a horizontal section through the calyx, about halfway up, would form two sides of a roughly triangular figure. That on the right is very slightly broader than the other. The two other radials, which lie on either side of the smallest basal (Pl. VI. fig. 2), are little more than half the breadth of the larger radials; they lie in one plane, and would form, in section, a base to the triangular figure slightly longer than either of the two sides. The suture between these two smaller radials is obscured by anchylosis. Each of the radials is rounded from side to side, so that the sutures lie in grooves, which are of varying depth. The interradial groove into which the adoral angle of the largest basal projects is by far the most marked. The opposite groove, that, namely, into which the

smallest basal projects, is, oddly enough, the next in depth; but the suture-line cannot be seen lying in it. The groove to the right of that last mentioned is very little less marked, but that to the left is a very faint depression; in both these grooves, however, the sutures are quite clearly seen. One of the two large radials was described above as slightly broader than the other; this radial lies between the deepest groove and the shallowest groove. Each of the two large radials has an extremely faint median longitudinal depression; and in the larger of the two this depression is bounded on either side by an equally faint elevation.

Ornament on Radials (Pl. VI. figs. 1, 2, 6).—On the surface of each radial the naked eye can just perceive a series of fine lines; these run across the radial from groove to groove, and are bent down in the middle in an aboral direction, so that each is parallel to the curved lower end of the radial; as seen with unaided vision or under a weak lens, this gives the radial an imbricated appearance. Seen under a higher power the apparent imbrication vanishes, the lines are not so regular, and have a tendency to run in sets, the lines in each set occasionally anastomosing; it was this arrangement in sets that looked like imbrication to the naked eye. A still higher power shows that the lines are produced by the concurrence of minute granules similar to those observed on the basals (Pl. VI. fig. 6); the arrangement is not unlike the curved lines produced in iron filings by the approach of a magnet. The great resemblance of this ornamentation to the lines of growth in many species of *Serpula*, notably *S. vertebralis* and *S. tetragona*, the contemporaries of our crinoid, combined with other points of superficial resemblance to the fragments of those fossils, is very deceptive; but whereas the ornament of *Serpula* is a true imbrication, and is increased by weathering, the lines on this crinoid are merely superficial and are destroyed by attrition.

The Spines of the Radials.—Each of the radials is prolonged at its right upper corner into a process; in the present specimen only one of these is completely preserved, that, namely, belonging to the right of the two smaller radials (Pl. VI. fig. 2). The section of this process is an acute-angled isosceles triangle, with the base of the triangle facing inwards (Pl. VI. fig. 3). The process tapers to a point. Its length is, from the point whence it springs on the suture-line to its extremity, 2·5 mm.; and from the upper surface of the radial to its extremity, 1·6 mm. Each of the two larger radials possessed a similar process; but that of one is broken off halfway up, while that of the other is broken off at its base. The left of the two smaller radials possessed only a very small process in the same position, which is just visible to the naked eye (Pl. VI. fig. 2). Similarly each of the radials is prolonged at its left upper corner into a process. The relative size of this process, as compared with the apposed right-hand process of the next radial on the left, is variable; it appears usually to have been shorter. In the case of the left-hand larger radial, this process is connected with the process of the right-hand smaller radial mentioned above as being the only

one completely preserved (Pl.VI. fig. 1): the two together form one spine, to which, however, the process now under consideration contributes but a small portion. In the case of the right-hand larger radial, the process is connected with the process of the left-hand larger radial mentioned above as being broken off halfway (Pl. VI. fig. 1): in this instance the two processes appear to have been of almost the same size; this is consistent with the greater size in other respects of the right-hand larger radial. In the case of the left-hand smaller radial the spine of which it formed part is broken right off (Pl. VI. fig. 2); but, to judge from the suture, this process must have formed nearly half the spine, in thickness if not in length. In the case of the right of the two smaller radials this process is minute (Pl. VI. fig. 2), and it combines with the equally minute process of its neighbour to form a tiny ridge, which runs at right angles to the circumference up to the rim round the calycal cavity now to be described.

Between their respective processes the radials gently bend inwards and upwards towards the *Calycal Cavity*. The ventral aperture of this cavity is circular (Pl. VI. fig. 3); it is rather less than 1 mm. in diameter, and therefore smaller than the basal aperture. It is bounded by a slightly elevated rim, which connects the left process with the right process of each radial. There are no remains of arms, and I can distinguish no regular markings on the inbent surfaces of the radials between the spines, and no openings for canals (*cf.* Pl. VI. fig. 5).

Specimen B.—This resembles A in every essential character; I shall therefore merely indicate the points of difference. The *Basals* have been destroyed, but traces are left of that which in A was described as the largest basal. The basals appear to have passed up for a short distance on the inner side of the radials, so that the *Radials* rested in a groove on the upper surface of the basals. The union between the basal ring and the radials, in harmony with the tendency to anchylosis shown throughout the calyx, was apparently close; hence this specimen shows no clear articular or sutural surface at the aboral end of the radials. The *Interradial Sutures* are not so clear as in A, but the grooves show their former position; the groove between the two smaller radials is, however, not nearly so evident as in A. The left of the two smaller radials has, at three quarters of its height, on the left side, a relatively large protuberance; this has deflected the process in the left upper corner towards the left, and it therefore constitutes a larger portion of the spine at this angle than is usually the case: the right upper process of the next radial on the left is correspondingly atrophied. The *Ornament* of the radials is well preserved, and its essentially granular nature is more obvious than in A (Pl. VI. fig. 6). The three larger *Spines* are fairly well preserved, but the end of each is broken (Pl. VI. fig. 5); the small spine is a fine, well-marked ridge. The region of each radial lying between its processes is not bent inwards at quite so sharp an angle as in A; here, too, I can

find but the minutest trace of muscle-attachment, no true articular surface, and no canal-aperture (Pl. VI. fig. 5).

In the above accidental characters alone does this specimen differ from the former. There can be no doubt that the two belong to the same genus and to the same species.

Validity of the Genus.

It is hardly necessary to point out that the existence of two individuals, and those so nearly alike, almost entirely quashes the supposition that we have to deal with a mere abnormality. And it is in any case difficult to see of what known form this could be an abnormal variety. In all our collection there is nothing else like it; in existing crinoid literature I am unacquainted with anything of similar nature *. My ignorance, it is true, would prove little were it not shared by our greatest authority on the Crinoidea, Dr. P. H. Carpenter. Further, I have recently worked through every crinoidal fragment in the Museums of Strassburg, Freiburg i/B., Stuttgart, Tübingen, Donaueschingen, Schaffhausen, and Basle, also in the private collections of Herr E. Koch (Stuttgart), Dr. Schalch (Schaffhausen), Mons. E. Greppin (Basle), Mons. V. Gilliéron (Basle), also in the collection Cartier (Basle Museum), and the collection Greppin, père (Strassburg Museum); in all these there is not a single specimen of the same or of similar nature. Perhaps I may be allowed this opportunity of expressing to these gentlemen, and to those connected with the above-mentioned public institutions, my most hearty thanks for the kindness they, without exception, showed to me, and for the facilities that all afforded me in my work.

We must therefore conclude that this unique form is *sui generis*; but, before giving a diagnosis, it will be advisable to compare it with other crinoids.

Systematic Position.

The general resemblance of this new genus to some Eugeniacrinidæ is obvious, although it by no means presents the characters of that family as defined by Prof. K. v. Zittel† and by Mons. P. de Loriol‡. The latter writes:—"The crinoids constituting this family are composed of a calyx supported by a stem that is fixed by a root to sub-

* E. F. von Schlotheim, in 'Nachträge zur Petrefactenkunde,' 2 Abth. (Gotha, 1823), p. 102, mentions a Eugeniacrinid "calyx of somewhat altered form, which occurs, though very rarely, in the neighbourhood of Amberg." This is figured in the Atlas 'Versteinerungen aus v. Schl.'s Sammlung,' pl. xxviii. fig. 6 *g*, and a facsimile is annexed. It appears to have had 4 R, with three large spines and one smaller one. In other points it is not like our specimens; but, as it probably came from the "Brauner Jura," it may be a transition form, as in fig. 2, III, p. 165.

† Handbuch der Paläontologie, Paläozool. I. i. p. 384 (München, 1880).

‡ Paléont. Française; Invertébrés; Terrain Jurassique, xi. 1ère partie, Crinoides, pp. 74–5 (Paris, 1882).

marine bodies. The calyx is formed of radials alone, without basals. The first radials, which may vary in number, are closely united to one another, and enclose the true calycal cavity. Their united base is truncate or depressed for the articular facet of the stem; they may also, but more rarely, rest on a well-characterized 'article basal.' Their upper face bears a well-developed articular surface, on which is articulated a second radial, surmounted by a third axillary radial, The arms are scarcely known. One species only * shows them to the number of ten, not branched, rolled up, and composed of a single series of thick joints. The stem-joints are usually long, and were probably few in number; their articular facets bear ridges or irregular crenellations. There are no cirri. The root is a little calcareous mass or a flattened incrustation." De Loriol includes in this family the genera *Eugeniacrinus, Phyllocrinus, Eudesicrinus*, and *Tetracrinus*. On the grounds of general resemblance in the disposition of the radials, of the entire absence of the radial processes so characteristic of most, though not all Eugeniacrinidæ, and of the single-jointed stem, *Eudesicrinus* must be referred to the Holopidæ. Dr. P. H. Carpenter, who has already made this correction†, believes that the peculiar support consists of basals fused to one another and to a single stem-joint below. In this I follow Carpenter in preference to de Loriol. Carpenter, however, also believes that the "article basal," usually known as the top stem-joint, of Eugeniacrinidæ represents fused basals‡. If this were true, the distinction between the two families Holopidæ and Eugeniacrinidæ would seem confined to the difference in number of stem-joints; while, on the other hand, the Eugeniacrinidæ would be very closely allied to *Rhizocrinus* and the Bourgueticrinidæ. On this point, however, I am at present unable to agree with Dr. Carpenter. It will be necessary to recur to this question; meanwhile I adopt the explanation of Beyrich and Zittel, that the basals have been included and absorbed by the radials.

From the Eugeniacrinidæ, as thus conceived and limited, the form with which we have now to deal, differs in the following characters:—First, in the presence of what I have called a "basal ring," which I believe to represent fused basals; secondly, in the absence or extremely slight development of an articular surface for a second radial; and I think we may add as thirdly, that it differs in the number and arrangement of its radials. It is true that *Eugeniacrinus* and, possibly, *Phyllocrinus* have occasionally only four radials, and that *Tetracrinus* has that number as a rule. The common opinion is that such a variation is rather common in *Eugeniacrinus*; absolutely, this may be true; but, having regard to the enormous number of specimens, I believe that the relative

* *Eugeniacr. nutans*, Goldf. (*vide* Zittel, *loc. cit.* fig. 273 *h*).—F. A. B.

† Report 'Challenger' Zoology, vol. xi. part xxxii. Crinoidea: I. Stalked Crinoids, p. 216 (London, 1884).

‡ "On the supposed absence of Basals in the Eugeniacrinidæ and in certain other Neocrinoids." Ann. & Mag. Nat. Hist. 5th ser. xi. pp. 327–334 (May 1883).

number of four-rayed individuals is extremely small. Although such a specimen would assuredly be preserved by every one that noticed it, yet there is among the many hundred calyces of *Eugeniacrinus* at the British Museum only one such form, and in all the collections I examined on the continent I succeeded in finding two at most; one of these is a *Eug. nutans*, at Tübingen, and is figured in Quenstedt's Atlas to the 'Petrefactenkunde Deutschlands,' Taf. cv. figs. 179–181; the other is a *Eug. caryophyllatus*, at Stuttgart. Rosinus figures a four-rayed *Eug. caryophyllatus* under the name "Corpus stellare tetragonum et tetractinobolon" *. A. Goldfuss figures a four-rayed *Eug. caryophyllatus* and *Eug. nutans* †; other writers, such as L. Agassiz ‡, have alluded to the fact; but the foregoing are all the instances I can find. Further, in those abnormal forms and in *Tetracrinus* the radials are quite regular and equal in size; but in the present genus two of the radials are much smaller than the other two, and show a very strong tendency to fusion; this is accompanied by a corresponding atrophy of the basal in their interradius, and of the processes that would otherwise have formed a spine. Consequently, to apply the language of Rosinus, we have a body that is morphologically "tetractinobolon," but actually "trigonum." This character, strongly emphasized by the three spines and the three basals, causes me to suggest for the genus the name *Trigonocrinus*.

It is unnecessary to point out that *Trigonocrinus* cannot be a species, or even a close ally, of *Tetracrinus*, for the latter genus has no radial processes. The peculiar character of the processes in *Trigonocrinus*, forming what I have called the "spines," allies this genus more closely to *Phyllocrinus* than to any other Eugeniacrinid. In *Phyllocrinus* the processes of two contiguous radials unite to form a sort of "petal," whence the generic name. The five petals, the "*folioles interradiaux*" of de Loriol, are triangular in section, but the apex of the triangle is directed inwards, and not outwards as in our specimens of *Trigonocrinus*. In most *Eugeniacrini* the conjoined processes are shaped like spear-heads (*fer-de-lance*), they are more developed and attain a greater length in *Phyllocrinus*; this is, indeed, the main difference between the two genera. Their relatively elongate character in *Trigonocrinus* is the main point of resemblance between this genus and *Phyllocrinus* (Pl. VI. fig. 12).

The notch (*échancrure radiale*) between each pair of petals which bears the articular facet for the second radial is in *Phyllocrinus* extremely narrow, while the facet occupies the whole thickness of the first radial, and is not so deeply sculptured as in *Eug. caryophyllatus* (see Pl. VI. fig. 13). The arms in *Phyllocrinus* must have been very thin, and de Loriol hazards the conjecture that they did not

* M. R. Rosinus, 'Tentaminis de Lithozois . . . Prodromus, sive de Stellis Marinis,' &c. tab. iii. Classis B, No. 3 (Hamburg, 1719).

† See Appendix, p. 167.

‡ "Prodrome d'une Monographie des Radiaires ou Echinodermes." Mém. Soc. Sci. Nat. Neuchâtel, i. (1835), pp. 168–199 (1836): on pp. 195–6, *sub Eugeniacrinus*, and footnote (1).

branch, and that they were attached directly to the first radials; this, he admits, would be abnormal. That arms were actually present, though doubtless minute, is proved by the aperture of a canal in the middle of the articular facet of the first radial. Besides this, the depressions for the attachment of the various muscles and the articular ridge are quite evident. In *Trigonocrinus*, however, the process of degeneration of the arms has advanced so far that not only are the muscular attachments all but invisible, but the canal has no longer any opening, or, at least, none that can be distinguished with a strong lens (Pl. VI. fig. 5). Correlated with this is the slightly different shape of the petals, or rather spines, which no longer present a flat surface against which the second and third radials might fit, as they do in *Phyllocrinus* and *Eug. caryophyllatus*. Whether any rudiments of arms were still present in the living animal, we cannot say; from the evidence as yet before us, it does not, however, seem likely that such rudiments can have been more than fleshy processes.

Another point of distinction is the small, round, ventral aperture of the calycal cavity with its enclosing rim. In this there are no traces of radial furrows, and it is altogether very unlike the broad, shallow basin of most other Eugeniacrinidæ; but some of the later Oxfordian species of *Phyllocrinus* show a gradual deepening and narrowing of the calycal cavity, and in them the radial furrows are rather fainter than usual—*e. g.* *P. fenestratus*, Dumortier, and still more *P. granulatus*, d'Orb. (Pl. VI. fig. 15). It is noticeable also that the latter species is distinguished by an ornamentation of granules, which are not unlike those of the present species of *Trigonocrinus* (Pl. VI. fig. 14). The rim round the calycal cavity, like the thickened mouth of a bottle, represents, of course, the raised wall on the inner side of each radial facet; it is the last relic of articulation.

The last and most important character in which *Trigonocrinus* differs from other Eugeniacrinidæ is the mode of union between stem and radials. In *Eug. caryophyllatus* the radials are prolonged downwards, *i. e.* dorsalwards, far from the calycal cavity; they often narrow to a stalk, supporting the broad and flat ventral portion of the calyx; a clove-like appearance is thus produced, whence the specific name. In *Eug. aberrans* this downward extension of the radials is extraordinarily marked *. In both these species the radials are often fused, and their aboral ends are cut off quite straight. The flat surface thus formed is far removed from the calycal cavity, and it is pierced only by a small axial canal. It is a sutural surface, and marked, like the corresponding upper surface of the top stem-joint, by pustules that have a tendency to run into striæ (Pl. VI. fig. 10). In *Eug. nutans* this sutural surface is slightly concave, while the upper surface of the top stem-joint is convex in proportion. In *Eug. Mussoni* the concavity and corresponding convexity are somewhat greater. In all typical species of *Phyllocrinus* this concavity has become a deep, narrow, circular hole; into this was inserted either the whole of the top stem-joint, or a cylindrical prolongation from it,

* De Loriol, 'Pal. Franç.' *loc. cit.* pl. xv. figs. 4–6.

as in *Eudesicrinus* *. Specimen A shows at its aboral end a similar, deep, narrow, circular cavity. We might suppose that the joint of the stem succeeding this was partially excavated for the reception of a portion of the chambered organ ; but a comparison with the more closely allied forms of Eugeniacrinidæ suggests rather that the upper part of the top stem-joint was inserted in this cavity. Whatever was the mode of union, there are now no traces of a ridged sutural surface. So far *Trigonocrinus* approaches *Phyllocrinus* ; but from all the Eugeniacrinidæ it appears to differ in the presence of a basal ring. De Loriol says of the Eugeniacrinidæ that there are no basals ; the radials, he says, repose directly on an "article basal." This "article basal" is, according to him, the top stem-joint ; in some species it may possibly have received a small portion of the chambered organ—*e. g.* *Eug. nutans*, Goldfuss, *Tetracr. moniliformis*, Münster, and *Eug. mayalis*, Morière. This, however, is very doubtful, and it is certain that in *Eug. caryophyllatus*, Schloth., *Eug. Dumortieri*, de L., *Eug. Moussoni*, Desor, *Eug. crenulatus*, d'Orb., *Eug. aberrans*, de L., and in most if not in all of the *Phyllocrini*, the chambered organ was situated within the radial circlet far above the "article basal." The idea that basals are entirely unrepresented is, however, quite opposed to our present knowledge of crinoid morphology. The question to be answered therefore is:— Where are the basals in Eugeniacrinidæ?

Dr. Carpenter supposes that the "article basal" consists of anchylosed basals †. His arguments are (1) analogy with *Rhizocrinus* and *Bathycrinus*, (2) doubtful homology with *Eudesicrinus* and *Holopus*, (3) interradial ridges on upper surface of "article basal" in *Eugeniacrinus* and *Tetracrinus*, (4) arrangement of internal canals. I shall consider these in order.

(1) This argument is only of value as showing how forms once supposed to be without basals have been proved to possess them. J. S. Miller likewise supposed that the "article basal" in *Eugeniacrinus* represented basals. He, however, imagined that he had before him young individuals, "in which an insufficient calcareous secretion has not as yet distinctly separated the plates, they might very possibly assume the regular character of the genus Encrinites in a more advanced stage of their growth" ‡. Dr. Carpenter's hypothesis is the converse of Miller's. To prove Miller right, we should require older specimens in which the sutures were becoming evident. Carpenter, on the other hand, could prove his case by producing young specimens in which the sutures had not yet been obscured. No such specimens, old or young, have yet been found.

(2) The top part of the support in *Eudesicrinus* does, it is true,

* De Loriol, 'Pal. Franç.' *loc. cit.* p. 161.

† P. H. Carpenter, "On the Supposed Absence of Basals," &c., *loc. cit.* p. 329 ; and Report 'Challenger' Crinoidea, I. Stalked Crinoids, p. 227.

‡ 'Natural History of the Crinoidea,' Bristol, 1820, p. 113. In young *Encrinus gracilis* the sutures between the basals are invisible ; *vide* E. Beyrich, "Ueber die Crinoideën des Muschelkalks," Abh. d. k. Akad. d. Wiss. Berlin, Phys.-Kl. No. 1, pp. 1–49, pls. i. & ii.

probably consist of fused basals: but it wholly differs in appearance and position from the "article basal" of *Eug. caryophyllatus*, and probably of all Eugeniacrinidæ; nor could it in any case be used as a strong argument by Carpenter, since he himself has assigned that genus to a different family.

(3) Ridges are well known to be occasionally present on the upper surface of the "article basal" in such individuals as have the interradial sutures well marked. One is not tempted to ascribe to these ridges any morphological significance, seeing that their intensity is obviously connected with the depth of the suture-groove, and that similar ridges occur on the top stem-joint of Apiocrinidæ. But, says Dr. Carpenter, "in *Tetracrinus* and *Eugeniacrinus* the ridges are interradial." It is hard to see how they could be otherwise; and for the matter of that, it often happens in *Apiocrinus elegans*, Defr., non d'Orb. (=*A. Parkinsoni*, Schl.), that the top stem-joint has undergone interradial fission, in which case the joint below it shows interradial ridges *.

(4) Dr. Carpenter says †, "the so-called uppermost stem-joint of Eugeniacrinidæ ..... is pierced by five interradial canals, each of which forks just below the synostosis of this piece with the radials above. In *Encrinus*, *Apiocrinus*, *Millericrinus*, *Pentacrinus*, *Metacrinus*, &c., and in the larval *Comatulæ*, each of the basals is perforated by one of these bifurcating interradial canals; and no Crinoid is known with these canals situated anywhere else but in the basals. They lodge the five primary cords which proceed outwards from the chambered organ towards the circular commissure contained within the radial pentagon." This is very solid argument, and the major premiss will be accepted by everybody; all depends on the minor. Is Dr. Carpenter's description of the structure in *Eugeniacrinus* correct? He instances no authority, brings forward no evidence, and gives hardly any details.

With this it is interesting to compare the explicit account of Prof K. v. Zittel‡, based on evidence similar to that previously published by Prof. E. Beyrich §. Dr. Carpenter alludes to Beyrich's view ||; but I cannot find that he has anywhere seriously discussed it, or examined the evidence. Von Zittel's account is as follows:—"The central canal of the stem enters the massive calyx composed of the anchylosed radials; it gradually broadens upward, and at a short distance gives off 5 interradial canals. These run under the floor of the visceral cavity and very soon bifurcate. The branches enter the radials, unite there, each with the converging branch of an adjacent basal canal; they then proceed, close to one another,

* See also J. S. Miller, 'Nat. Hist. Crin.' p. 32, line 9 *et seq.* pl. vii. figs. 1–6 and 8–10.

† Absence of Basals, &c., *loc. cit.* p. 329.

‡ Handb. d. Paläont. p. 385.

§ Zeitschr. deutsch. geol. Ges. xxi. p. 835 (Berlin, 1869), Protokoll d. Sitzung, 15 September: "Herr Beyrich legte Präparate von Eugeniacrinuskelchen vor, u. s. w."

|| Absence of Basals, &c., *loc. cit.* p. 327.

through the middle of the radial towards the upper articular surface. At the point where the branches unite is a ring-canal, which joins together all the radial canals. The course of these canals proves that basals were originally present, perhaps even in the young stages, and that their atrophied remains are perhaps still enclosed within the adoral (*oberen*) portion of the radials." It will be noticed that v. Zittel and Beyrich rely on the same major premiss as Carpenter. Seeing that Carpenter had omitted to notice v. Zittel's argument, I feared that the minor premiss might have broken down, and that the arrangement of the canals was not as above described. But Professor von Zittel has been kind enough to inform me that his account was based on an examination of silicified and weathered specimens, in which the canals were clearly preserved, and of a series of thin transverse sections; he is perfectly certain that his account is correct, the more so in that it had been verified by Prof. Beyrich. The same arrangement of canals obtains in *Phyllocrinus* *; here too, then, the basals are represented in the calyx. It is true that no Eugeniacrinid has hitherto been found that shows clear traces of separate basals †, but this does not turn v. Zittel's position. Dr. Carpenter tells me that he has never seen the specimens, but still considers the structure as described by v. Zittel to be anomalous. With all deference to Dr. Carpenter, I submit that, till disproved, we are bound to accept the evidence of v. Zittel and Beyrich, even though the facts may clash with our own ideas of what is proper for a crinoid.

I therefore maintain that in previously known Eugeniacrinidæ the "article basal" is a top stem-joint ‡, and that the basals are represented on the inner side of the radials; and I infer that the top stem-joint is absent from our specimens of *Trigonocrinus*, and that the "basal ring" does represent fused basals. It may further be observed, in support of this conclusion, that this basal ring is totally unlike the solid top stem-joints of other forms, that it is closely attached to the radials, and that, in accordance with v. Zittel's explanation, it partly projects within them.

Accepting v. Zittel's argument, we shall by no means consider it odd to find a genus of the Eugeniacrinidæ displaying basals. What is odd is that these basals should be manifested in a primitive position by a genus that in all other respects seems nearer to the end of the series, and therefore further away from the primitive basal-bearing form—a genus, too, in which not only anchylosis, but actual atrophy of calycal elements has proceeded to a far greater extent than in any other crinoid, except *Gymnocrinus Moeschi*, de Loriol.

* V. Zittel, 'Handb. d. Paläont.' p. 386.

† One might refer to E. F. von Schlotheim, 'Nachträge zur Petrefactenkunde,' 2 Abth. p. 102 (Gotha, 1823), and Atlas, Versteinerungen, &c., pl. xxviii. f. 6. b, von der Seite, c, von oben, und d, von unten, eines abweichendes Kronenkopfs. Apparently *Eug. Moussoni*; 6 d shows an inner circlet of 5 plates, of which the radial position is possibly due to an artist's error.

‡ "I cannot help thinking that the name 'article basal' is an unfortunate one, as being calculated to mislead."—P. H. Carpenter, 'Absence of Basals,' &c., *loc. cit.* pp. 331–2. It certainly has nothing to do with basals.

It may, however, be explained on this very principle. In other Eugeniacrinidæ, notably in *E. caryophyllatus*, which is the central and most abundant species of this family, the body lay in a shallow basin on the summit of the first radials, and was protected by the overarching second and axillary radials. In the *Phyllocrini* this relation of the soft parts was maintained, but the protection afforded by the 2nd and 3rd radials was obviously less; there was accordingly a tendency to a deepening of the calycal cavity. In *Trigonocrinus* the protection afforded by the free radials, if indeed they existed, must have been inappreciable; accordingly we find the calycal cavity sunk right down into the first radials, which are relatively elongated and bent in above. Since this was of itself a return to primitive conditions, we are at liberty to regard the reappearance of basals as a case of correlated reversion. But the very specialized character of the calyx, as a whole, renders this explanation rather unsatisfactory. Personally, I prefer to explain the change on Lamarckian principles: since the viscera sank down between the radials, a heavier burden, both literally and metaphorically, was thrown on the lower part of the calyx; the basals could once again be of service—consequently, instead of atrophying or becoming absorbed, they resumed their old function, and once again formed a structural element enclosing a part of the calycal cavity, as in Palæozoic crinoids, and supporting what is in normal crinoids the five-chambered organ, which here no doubt had only four chambers, and one of those minute. This explanation seems to me so much better than the former, that I cannot conceal my regret for the adverse criticism it would meet with from the school of biologists at present to the fore in England. Is it not, however, possible that both causes operated at the same time?

Generic and Specific Diagnoses.

Such, then, is my interpretation of the structure observed in this singular form; and in accordance with this the diagnoses are framed. It was necessary that the description of so anomalous a form should be full, otherwise there would have been a danger of missing out points that future knowledge may prove to be important. Interpretation was also necessary; for, even if it prove erroneous, it will ensure the correct understanding of the diagnoses.

Trigonocrinus, gen. nov.

Calyx roughly triangular or trilobate in section. Basals four, but one so atrophied as to be almost invisible; all fused into a basal ring. First radials four; the two on either side of the smallest basal half the size of the others, thus maintaining the triangular symmetry; all closely united, with each suture-line in a groove. Processes of radials well developed, forming spines homologous with the petals of *Phyllocrinus* (*folioles interradiaux*); except the adjacent processes of the smaller radials, which only form a minute ridge. Articular surface of radials curved gently inwards and upwards;

muscular impressions indistinct or absent; no articular ridge; no canal-aperture. Arms unknown; ? represented by fleshy appendages. Calycal cavity contained in first radials; with small round ventral aperture, surrounded by a rim which is the only relic of a muscular attachment. Stem unknown.

It is hard to see how the animal obtained its food; and this suggests that it was free-swimming, an idea countenanced by the great lightness and strength of the calyx. On the other hand, arms unfit for obtaining food must have been still more unfit for swimming. Further, to take to a free life is a progressive development, and analogy renders it unlikely that such a form should be the last of its race. This latter argument also prevents us from supposing that the animal was parasitic on some soft-bodied creature, to which mode of life its structure seems admirably adapted. We can only suppose that *Trigonocrinus* was a form degenerate, not owing to conditions or to any mode of natural selection, and not from any fault of its own, but in obedience to those laws, as yet half understood, that govern the life of a race no less than of an individual.

Of this genus only one species is known.

Trigonocrinus liratus, sp. nov.

Calyx rather more elongate than in the known species of *Phyllocrinus*; basals ornamented with minute granules; radials ornamented with similar granules run into curved ridges, which, owing to their differing intensity, give an imbricated appearance; spines triangular in section, with the base of the triangle directed inwards, the apex outwards, the angles often rounded.

In describing a totally new genus from only two specimens, both of the same species, it is hard, if not impossible, to discriminate generic, specific, and merely varietal characters; but an examination of the species in other genera of Eugeniacrinidæ leads me to believe that the above characters are of specific value.

I have referred this genus without hesitation to the Eugeniacrinidæ; at the same time it is clear that its adoption will necessitate a rewriting of the existing description of that family, even of that by Prof. v. Zittel. This, of course, does not mean that the family Eugeniacrinidæ is not a perfectly good one—it is merely one more instance of the great difficulty of defining any natural assemblage of living beings, so as to include all forms connected with it by direct blood-relationship. Should this paper instigate, as I hope it will, renewed research among the fossil-beds of Würtemberg and Bavaria, it is possible that more allied forms may be found. The task of redefinition is therefore better left over for the present, with the added hope that it may fall into more competent hands.

Deviation from a Pentamerous Type.

It is impossible to leave this striking form without some remarks on its most remarkable character, namely, the complete loss of one

radius with its adjoining interradius, and the decrease in size of two radii and the interradius between them.

Instances of deviation from regular penta-symmetry are not uncommon among Echinodermata. The cause of such deviation may be one of many. Thus, the increased importance of the anal interradius in most Crinoidea from Palæozoic strata tends to hexa-symmetry; the structure here is affected by function: Herbert Spencer* has compared the typical upright condition of the iso-pentamerous crinoid to that of an upright flower; surrounded on all sides by an equal medium, it retains its symmetry, but should the position on the stalk be altered, the radii differ in their growth, *e. g. Eug. nutans*, *Eudesicrinus*, *Holopus*: in the later and more differentiated among the Echinoidea a marked bilateral symmetry is superinduced on the ground-plan; the advantage of this to a crawling animal is obvious.

The methods through which organic forms undergo change have been variously classified, and the late Dr. Asa Gray distinguished as many as 9†. The deviations from the central type of Crinoidea may be referred to one of three categories, which may, for brevity, be termed:—(i) Sport, (ii) Hypertrophy or Atrophy, (iii) Fusion or Fission. In the consideration of homologies it is important that these methods should be discriminated.

(i) Under the term "Sport" I include the sudden addition or subtraction of a part, the latter being the more common. The 4-rayed specimens of *Eugeniacrinus* alluded to above, or the 6-rayed *Eug. caryophyllatus*, also figured by Rosinus‡, are parallelled by similar variations in all polymeric forms. The shortness of the list in the appendix, though I fear it is not an exhaustive one, shows the relative rarity of such cases in the later Crinoidea. Some of the examples prove that it is possible for a crinoid to grow to full stature and to enjoy life while devoid of one of its pentameres; but there is nothing to show that its peculiarity is inherited by its offspring. There is, however, always the chance that, perhaps under changed conditions, a mere sport may be in earnest of use to the animal; it would thus be preserved and, possibly, perpetuated. Many sports, of which man at all events cannot see the advantage, have been truly transmitted, and the descendants thus modified have in many cases ousted the original form§. It is, as we have seen, a general belief that *Eugeniacrinus* shows a tendency to tetramerism. Perhaps it does show a greater tendency than some genera, *e. g. Pentacrinus*. The odds in favour of such a sport becoming permanent are therefore greater, and *Tetracrinus*, in accordance with its perfect symmetry, is best explained in this manner; it is further to be noticed that the genus only contains one species, which had a very short geological life.

* 'Principles of Biology,' issue of 1880, vol. ii. p. 178.

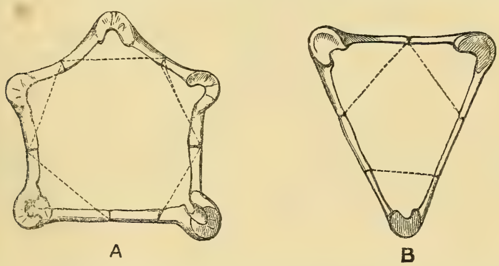
† P. E. Geddes, art. "Morphology," Encyclop. Brit. ed. ix. vol. xvi. p. 844 (Edinburgh, 1883).

‡ *Loc. cit.* tab. iii. Classis B, No. 1.

§ For several instances, with references, see St. George Mivart, 'On the Genesis of Species,' 2nd ed. chap. iv. pp. 112–117. London, 1871.

(ii) The method of "Atrophy" differs from the method of Sport in its gradual character, and in the number of stages passed through before the same result is reached as is attained at one stroke by the sport. And even then the resultant figure is not the same: atrophy of one part nearly always depends on the hypertrophy of another part; hence symmetry is destroyed. Thus in *Eudesicrinus* and *Holopus* one radial grows large and the others small, the calyx is crookedly set on the stem and is lop-sided*; *Eug. nutans* is similarly affected; in *Torynocrinus canon*, Seeley, the asymmetry amounts to distortion†; and in *Gymnocrinus* one ray seems to have usurped the place of all the others. Or atrophy may take place in two rays, thus changing the symmetry from pentagonal to trigonal, as in *Baerocrinus*. Dr. P. H. Carpenter, however, seems to consider this as a persistent sport, for he writes:—"It is, perhaps, best regarded as a permanent larval form, which has only developed three of its five arms." In the allied genus *Hybocrinus*, however, we seem to see gradual atrophy of one arm; but of this, too, Dr. Carpenter writes:—"This may be, and probably is, one of the variations of growth to which this early and simple type is subject"‡. Anyhow

Fig. 1.—*Diagrams of* Hybocrinus *and* Baerocrinus.



A. Calyx of a typical *Hybocrinus dipentas*, as seen in outline from above.
B. A similar view of *Baerocrinus Ungerni*. The two edges of every arm-bearing radial are joined by dotted lines. After Grewingk.

there is plenty of room for a different opinion. Similar irregularity is seen in *Pourtalesia* among Echinoidea, and in *Pentephyllum* among Blastoidea. It is further to be observed that, whereas a sport is usually confined to individuals, producing an unstable

* For remarks on the bilateral symmetry thus induced, see C. Wyville Thomson, "On the Structure and Relations of the genus *Holopus*," Proc. Roy. Soc. Edinburgh, vol. ix. pp. 405–410 (1877); on p. 408: and P. H. Carpenter, "The Stalked Crinoids of the Caribbean Sea," Bull. Mus. Comp. Zool. Harvard, x. no. 4, pp. 165–179 (Cambridge, U. S., 1882); on p. 178.

† H. G. Seeley, "Notice of *Torynocrinus*" &c., Ann. & Mag. Nat. Hist. ser. 3, xvii. pp. 173–4. Figured in Seeley's 'Phillips, Manual of Geology, Part I. Phys. Geol. & Palæont. (London, 1885), p. 487, f. 100.

‡ P. H. Carpenter, "On the Relations of *Hybocrinus*, *Baerocrinus*, and *Hybocystites*," Quart. Journ. Geol. Soc. vol. xxxviii. pp. 298–312, pl. xi. (1882); see p. 304 and fig. 2, A, B. I here take the opportunity of expressing my thanks to Dr. P. H. Carpenter for permission to use his figures, and for many other acts of kindness in connexion with the present paper.

variety, this method frequently results in a series of forms recognized as species and even as genera.

(iii) "Fusion" differs from the former methods in that no part is lost; the fundamental morphology of the calyx remains unchanged, and internal organs, such as the canals, bear witness to a former different state of things. Thus, in many Palæozoic crinoids the basals, typically five in number, become by concrescence 4, 3, 2, or even 1, while their relations to the rest of the calyx may be unaltered*. Compare also the fused basals of *Bathycrinus* and *Rhizocrinus*†. Of gradual fission I know no instances, but it may take place for all that. In *Marsupites testudinarius*, v. Schloth., the dorso-central is occasionally found divided into three or four irregular plates, and in *Apiocrinus* fission of the top stem-joint is not rare; but these variations are confined to individuals. Fission in a horizontal plane is, of course, common, but I am here referring to changes that take place parallel to the long axis of the crinoid.

The interest of *Trigonocrinus* in the present connexion lies in the fact that it is an example of all three methods of change. As such, it stands alone; and only by appreciating their distinctness can we understand how it has reached its present structure. Dr. P. H. Carpenter suggested to me a comparison with *Allagecrinus*; the changes in that form are of remarkable interest, none of which was lost by the authors of the genus‡. A detailed comparison shows many curious points of resemblance between the two forms—*e. g.* fused basals, separate radials, interradial sutures in grooves, atrophy of a radial with imperfect articular surface, absence of central canal in radials of young *Allagecrinus* (see Pl. VI. figs. 17, 18). But, as the authors point out, the characters of *Allagecrinus* are those of an undeveloped rather than of a degenerate form; further the deviation from pentamerous symmetry is brought about by Atrophy alone.

The evolution of *Trigonocrinus*, on the other hand, appears to have been as follows:—Starting from a normal Crinoid (fig. 2, I, p. 165) with five basals, 1, 2, 3, 4, 5, and five first radials, *a*, *b*, *c*, *d*, *e*, a Sport effected the loss of one radial, *b*, and its corresponding basal, 2. Thus arose the form in fig. 2, II, with four radials and four basals. One side of the calyx then increased at the expense of the other side; basals 3 and 5 slightly diminished in size, while basal 4 atrophied to a considerable extent; radials *a* and *c* remained large, while radials *e* and *d* atrophied: such a stage is represented in III; no actual form of this composition is known, but it is closely parallelled

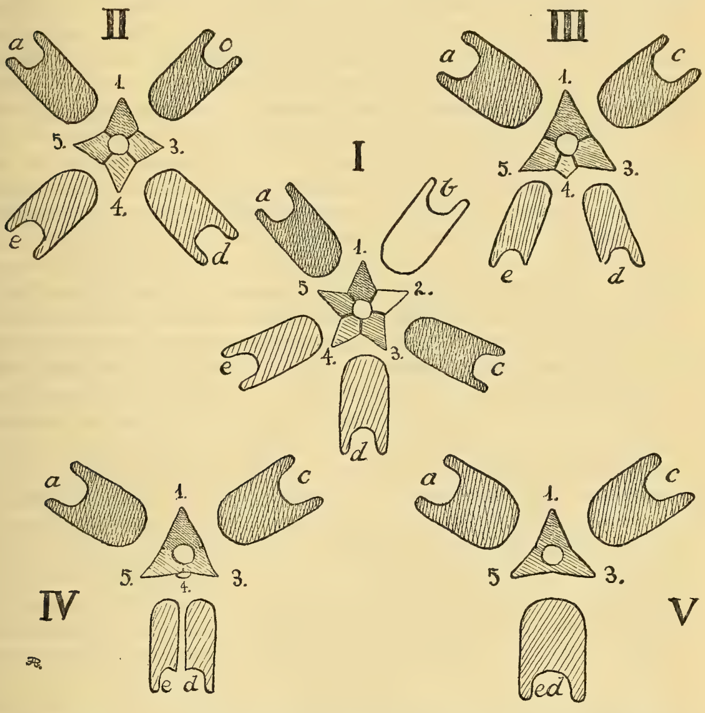
* See Ch. Wachsmuth and F. Springer, 'Revision of the Palæocrinoidea,' author's copy, part i. pp. 16–19, and Proc. Acad. Nat. Sci. Philad. vol. for 1879, part iii. pp. 240–242. Philadelphia, 1880.

† P. H. Carpenter, 'Challenger' Report. Zoology, vol. xi. part xxxii. . . . The Stalked Crinoids, see pp. 226–228 and 248–253. London, 1884.

‡ P. H. Carpenter and R. Etheridge, Jun., "Contributions to the Study of the British Palæozoic Crinoids. No. 1. On *Allagecrinus*, the representative of a new Family from the Carboniferous-Limestone series of Scotland." Ann. & Mag. Nat. Hist. ser. 5, vol. vii. pp. 281–298, pls. xv. xvi. London, 1881.

by a 4-rayed *Eug. nutans*. The present species has reached a stage (IV) in which the basals are fused into a basal ring, and the atrophied radials, *e* and *d*, are usually, if not always, fused; basal 4 has all but disappeared. One step more of Atrophy, and all trace of basal 4 and of the spine in that inter-radius would have vanished; one step more of Fusion, and radials *e* and *d* together would be, to

Fig. 2.—*Diagrams illustrating probable Evolution of* Trigonocrinus.



In each figure the corresponding basals are numbered 1, 2, 3, 4, 5, respectively, and the corresponding radials lettered *a, b, c, d, e*, respectively; the numbers are arbitrary, as one cannot determine the true orientation of these fossils; greater depth of shading indicates greater tendency to Hypertrophy, less depth to Atrophy:—I. Primitive iso-pentamerous type, cf. *Eugeniacr. caryophyllatus*. II. Loss of radial *b* and basal 2 by Sport, producing iso-tetramerous type, cf. *Tetracrinus*. III. Hypertrophy of radials *a, c* and basal 1. Atrophy of basal 4 and, to a less extent, of the remaining calycal elements. IV. Atrophy continued. Fusion in part of radials *e, d*, and complete of basals 1, 3, 5. *Trigonocrinus*-stage. V. Complete Fusion of radials *e, d*, and final Atrophy of basal 4. Future stage.

all appearance, the equivalent of either *a* or *c*. Such a form, of which V gives the scheme, would doubtless have been described as "a triradiate crinoid!"—assuming that it were recognized as a crinoid at all.

Pentamerous symmetry still dominates the Crinoidea. Rummaging the records of the past, we do find 4-rayed genera—*e. g. Tiaracrinus quadrifrons*, Schultze, *Tetramerocrinites formosus*, Austin *, and *Tetracrinus*; but in the long run every attempt at this and other compositions has failed. Nature, "so careful of the type," has probably kept it true by a restraining selective action dependent on obvious mechanical principles. In the pentamerous calyx every line of weakness is met halfway by a solid plate: but whenever a hexamerous or tetramerous condition is attained, the lines of weakness pass right across the calyx; such forms are therefore liable to destruction. Simple Fusion does not alter original form; so far as this goes, the tripartite base of many Palæozoic crinoids is still of pentamerous symmetry. Atrophy of the two larger basals and Hypertrophy of the smaller one are required to induce iso-trimerism †. This once attained, the same opposition to lines of weakness is found, and structural equilibrium is maintained. The other classes of the Echinodermata, while similarly retaining penta-symmetry as the normal plan, do often produce 4-rayed and 6-rayed forms. A few examples are quoted in the Appendix. Some writers have regarded these as due to reversion ‡. However that may be, we may well suppose that the conditions, mechanical or otherwise, which are now merely restraining, were once evolutionary in their action. The constant occurrence in the "Ur-Gruppe"—Cystoidea—of tetramerous or hexamerous systems and, *à priori*, the simpler nature of such division, renders it quite possible that the Echinodermata were at first less definite in their plan of structure; and that, of the many types which at first took the field in the struggle for existence, the pentamerous type was victorious; finally, that this type has become fixed, and to it all Echinodermata subjected, through methods above described, controlled by natural selection §.

Such a view would lend fresh interest to the stem-structure prevalent in the Larviformia, W. and S. Here, as a general rule, four, and not five, canals surround the central canal of the stem. True, this is not invariably connected with four radii in the calyx; at the same

* Perhaps only a sport. T. and T. Austin, "Description of several new Genera and Species of *Crinoidea*," Ann. & Mag. Nat. Hist. ser. 1, xi. pp. 195–207 (London, 1843); see p. 203.

† See E. Beyrich, "On the Base (Pelvis) of the *Crinoidea Brachiata*," Ann. & Mag. Nat. Hist. ser. 4, vii. pp. 393–411, 1871. Translated by W. S. Dallas from Monatsber. d. k. preuss. Akad. d. Wiss. zu Berlin, part for Jan. 1871, pp. 33–55.

‡ Wilhelm Haacke, "Zur Morphologie der Seeigel-schale," Zoologischer Anzeiger, herausg. J. V. Carus, viii. Jahrg. pp. 490–493 (Leipzig, 1885); and "Ueber die ursprünglichen Grundzahlen der Medusen und Echinodermen," *ibid.* pp. 505–507 (1885).

§ Some will no doubt regard the Holothurians with their soft bodies as furnishing a fatal objection to the above hypothesis. This, however, can only be in so far as the explanation relies on *mechanical* principles. But the spicules and degenerate plates of the Holothurians may be evidence that they are descended from ancestors in which the typical skeleton was better developed; they may stand in the same relation to the rest of the Echinoderms as the now naked Octopoda do to the shell-bearing Cephalopods.—*Note added by Author*, Jan. 15, 1889.

time this group does present some curious transitional types—*e.g.* *Pisocrinus*, *Triacrinus*, and (*apud* W. and S.) *Allagecrinus*. *Cupressocrinus* is a form that endeavours at times to break with old traditions, and appears with a triradiate or quinqueradiate stem *. To turn to another point: Dr. Carpenter considers the processes of the radials in *Antedon abyssicola* to be of a larval character †; these processes are homologous with the petals, spearheads, or spines of Eugeniacrinidæ; further they are exactly parallelled in many of the Larviformia, see drawing of *Haplocrinus* (Pl. VI. fig. 19). In the present state of our knowledge it would not be safe to connect the Eugeniacrinidæ more closely with these very ancient forms. It should, however, be remembered that the division between the so-called Palæocrinoidea and Neocrinoidea is caused very largely by the gap in the record at the close of the Palæozoic era; these two assemblages are admittedly heterogeneous, and cannot, on the face of things, represent divergent branches from an ancestral stock. A classification that shall adequately represent the true relations or, what comes to the same thing, the history of the Crinoidea, is yet to seek. When this has been found, the form described in the present paper will fall into its true place at the end of a long series; and to our examples of the law that senescent and degenerate forms resemble the adolescent forms in the early history of the same race, will be added one more, viz. *Trigonocrinus*.

APPENDIX.

Sudden Deviations from Normal Symmetry, chiefly in "Neocrinoidea."

Besides the examples given in the body of the paper (p. 155), I have collected the following instances; those for which no author is quoted are from my personal observations.

Holopus Rangi, d'Orb. Type specimen 4-rayed. A. d'Orbigny, in Guérin, 'Magasin de Zoologie,' Classe x. pl. iii. Paris, 1837. Coll. Jardin des Plantes.

Eugeniacrinus caryophyllatus, v. Schloth. A 4-rayed calyx, seen from above. A. Goldfuss, 'Petrefacta Germaniæ,' &c., Dusseldorf, 1826–1833: p. 163, pl. l. f. 3 *r*. Loc.? Coll. Bonn, Poppelsdorf Museum.

Eug. nutans, Goldf. A 4-rayed calyx. A. Goldfuss, *op. cit.* p. 164, pl. l. f. 4, *s*. Loc.? Coll. Bonn.

Tetracrinus moniliformis, Münst., reverts to pentamerous type. P. de Loriol, "Monogr. Crinoides Foss. de la Suisse," 3rd part, Abh. schweiz. pal. Ges. vi. Geneva, 1879: pl. xix. f. 39, 39 *a*, 39 *b*. "Article basal qui porte 5 côtes, ce qui indique 5 radiales." Loc. Oberbuchsitten. Coll. Cartier, in Basle Museum.

* L. Schultze, Monogr. Echinod. Eifl. Kalkes, Denkschr. k. Acad. Wiss. math-nat. Classe, xxvi. pp. 113–230 (Wien, 1867); see pl. i. f. 2 *b*, 2 *e*, 3 *d*, and pl. iii. f. 2 *i*.

† P. H. Carpenter, 'Challenger' Report, Zoology, vol. xxvi. part lx. The Comatulæ. London, 1888; see p. 192.

T. moniliformis, drops another radius. P. de Loriol, *op. cit.* pl. xix. f. 41, 41 *a*. "Autre article basal à trois côtes, ce qui indique 3 radiales seulement." Loc. Birnensdorf. Coll. Moesch, at Zurich.

Rhizocrinus lofotensis, Sars. A six-rayed specimen. P. H. Carpenter, 'Challenger' Report, Zoology, vol. xi. part xxxii.....'The Stalked Crinoids.' London, 1884: plate viii. f. 6 & 7. On p. 38 he writes "Four and six rays are more common in *Rhizocrinus* [*sc.* than in other recent Crinoids], and in very rare cases there may be seven."

Pentacrinus, sp. A 4-rayed stem-joint from the Chalk. Referred to by G. A. Mantell, 'Fossils of the S. Downs.' London, 1822, p. 183, No. 28. "A single vertebra of a quadrangular form, the angles rounded, the surface ornamented with figures resembling a floret of four rays." Coll. British Museum. [E. 5501.]

P. jurensis, Quenst. P. de Loriol, 'Paléont. Française,' 1e sér. Terr. Jurass. xi. 2 partie, pl. cxliv. f. 6, 6 *a*, 6 *b*, and p. 112. Paris, 1886. "Interverticille complet avec 4 faces seulement, dont l'une est absolument plane." The plane face bears a cirrus like the others. Upper Lias. Loc. May, Calvados. Coll. Deslongchamps.

P. subsulcatus, Münst. P. de Loriol, *op. cit.* pl. cxlv. f. 2, 2 *a*, p. 117. Paris, 1886. "Fragment de tige à 4 faces." Perfectly regular, 6 joints preserved. Middle Lias. "Original de Dumortier, pl. xxiii. f. 13, 14." Loc. Saint Fortunat. Coll. Muséum de Lyon.

P. Dumortieri, Oppel. P. de Loriol, *op. cit.* pl. clxii. f. 6, 6*a*, p. 186. Paris, 1887. "Interverticille complet d'une tige à 4 faces seulement." Quite regular; 8 joints. Bathonien. Loc. Celles. Coll. de Frère Pacôme.

P. dubius, Goldf. A small fragment of stem, regularly 4-sided, with smooth outer surface slightly depressed between the lobes ascribed to above species. Wellenkalk. Loc. Rohrbach bei Heidelberg. Coll. Basle Museum.

Balanocrinus subteres, Münst., sp. Stem-fragment with 4 rays, quite regular. Age and Loc. unknown. Coll. Basle Museum.

Bal. Bronni, v. Hagenow, sp. The articular surface shows 4 sectors, quite regularly disposed; this peculiar character is continued over the whole series of joints, 26 in number. Upper White Chalk. Loc. Rügen Is. Coll. Basle Museum, presented by Herr Rathsherr Albrecht Burckhardt, 1840.

Encrinus fossilis, Blumenbach (=*E. liliiformis*, Lamarck). A 4-rayed calyx and other abnormalities. A. v. Strombeck, "Beitrag zur Kenntniss der Muschelkalkbildung in N. W. Deutschland," Zeitschr. deutsch. geol. Ges. 1849, vol. i. 115–231, on pp. 157–167. Loc. "Erkerode und der nächsten Umgegend." And A. v. Strombeck, "Ueber Missbildungen von *Encrinus liliiformis*, Lam.," Palæontographica, iv. 169–178, and pl. xxxi. (Cassel, 1855).

E. fossilis, Blum. (=*E. liliiformis*, Lam.). A. von Koenen, "Beitrag zur Kenntniss der Crinoiden des Muschelkalks," Abhandl. der kgl. Gesellsch. d. Wiss. Göttingen, xxxiv. pp. 1–44 (1887). Describes two 4-rayed calyces of this species, "mit verstümmelten Armen," on p. 23. Loc. Elm.

Cupressocrinus crassus (*C. tetragonus*), A. Goldfuss. "Beiträge zur Petrefactenkunde. A. Ueber fossile Crinoiden." Nova Acta Ac. Cæs. Leop.-Car. xix. pt. i. pp. 329–352. Breslau u. Bonn, 1839. See p. 332, and pl. xxx. f. 3, 3 *a*. "Das Becken hat 5 Glieder, von welchem jedoch das fünfte als ein eingeschobenes Zwischenglied erscheint, da nur vier Rippen und vier Schulterglieder, so wie vier Arme folgen." This is referred by Schultze and Wachsmuth and Springer to *C. crassus*.

* *Antedon rosacea*, Linck, sp. P. H. Carpenter, 'Challenger' Report, Zoology, vol. xxvi. part lx. . . . The Comatulæ. London, 1888: p. 27. "A tetraradiate specimen." Coll. P. H. C.

* *Antedon*, sp. P. H. Carpenter, *op. cit.* p. 27, "A tetraradiate specimen . . . . of a Japanese *Antedon* in Dr. Döderlein's collection."

Antedon, sp. P. H. Carpenter, *op. cit.* pp. 27–28. "The only other six-rayed *Comatula* that I know is a small and dry *Antedon* in the British Museum. But the disc is sufficiently well preserved to show that the additional ray is inserted between the two of the right side (D and E)."

* *Actinometra paucicirra*, Bell. P. H. Carpenter, *op. cit.* p. 27. A quadriradiate specimen from Cape York.

Actinometra pulchella, Pourt., sp. P. H. Carpenter, *op. cit.* p. 27. A six-rayed form; disc concealed, so that symmetry of ambulacra cannot be made out; perhaps really pentamerous, but one radial, bearing 2 small rays; *cf. Allagecrinus* (*vide ante*, p. 164).

For other remarks on this subject see:—

G. G. Pusch.—'Polens Paläontologie,' &c., Stuttgart, 1837. "Ein proplematischer Entrochites tetradactylus," on pp. 8, 9, and Taf. ii. fig. 8, *a*, *b*, *c*, *d*, *e*. These are various 4-sided stem-joints, with tetragonal central canal.

Johannes Walther.—"Untersuchungen über den Bau der Crinoiden, mit besonderer Berücksichtigung der Formen aus dem Solenhofener Schiefer und dem Kelheimer Diceras-kalk." Palæontographica, xxxii. pp. 155–200, pl. xxiii–xxvi. Stuttgart, 1886. Phylogeny on p. 198. His remarks on embryology are quite inconsistent with our fuller knowledge.

H. von Meyer.—"Abweichungen von der Fünfzahl bei Echiniden nachgewiesen durch einen vierzähligen Cidariten und durch einen sechszähligen Galeriten." Nova Acta Acad. Cæs. Leop.-Car. xviii. pt. i. pp. 287–296, pl. xiii. f. 1–7. Breslau and Bonn, 1836. The specimens are *Cidaris coronata*, Goldf., and *Galerites albogalerus*, Leske, sp.

Further reference may be made to the papers by Beyrich, Haacke, and Wachsmuth and Springer already quoted (*ante*, pp. 164 & 166), and to the two 'Challenger' Reports of Carpenter, "The Stalked Crinoids," pp. 36–38, and "The Comatulidæ," pp. 27–28. In the

* "In all these individuals the anterior ray (A) is missing, so that the mouth, instead of being radial in position, is placed interradially between the rays E and B."—P. H. C. *loc. cit.*

latter place Dr. Carpenter quotes a few examples from other classes of the Echinodermata, and remarks on the same.

A detailed list and a comparison of all known examples of variation in symmetry would, it is probable, afford grounds for some more definite conclusion; this would especially be the case if we could more often tell which ray was missing or in which interradius one was added. Some general principle might possibly be discovered; but to attain this desirable end, the cooperation of specialists is needed.

EXPLANATION OF PLATE VI.

Fig. 1. *Trigonocrinus liratus*, specimen A, seen from side of largest basal, enlarged. 1 *a*, natural size, outline with spines restored. British Museum [E. 5502 a].

Fig. 2. *T. liratus*, specimen A, seen from side of smallest basal, enlarged. 2 *a*, natural size, outline with spines restored.

Fig. 3. *T. liratus*, specimen A, ventral aspect, the largest inter-radius towards top of plate; same scale as figs. 1 and 2.

Fig. 4. *T. liratus*, specimen A, dorsal aspect, showing basal ring, the largest basal towards top of plate; slightly larger scale than figs. 1, 2, and 3.

Fig. 5. *T. liratus*, specimen B, remains of depressions for attachment of arm on radial; compare with figs. 8 and 13. British Museum [E. 5502 b].

Fig. 6. *T. liratus*, specimen B, portion of radial surface further enlarged (circa 30 diam.), to show nature of ornament.

Fig. 7. *T. liratus*, plan of dissected calyx from evidence of specimens A and B. The basals are represented separately, though they are actually fused into a ring; the two smaller radials are also fused in whole or part.

Fig. 8. *Eugeniacrinus caryophyllatus*, calyx supported on the "article basal" (=top stem-joint, *mihi*). Note clear-cut processes of radials, and well-marked depressions for articulation of arms. $\times 2\frac{1}{2}$ diam. After De Loriol, Paléont. Franç. T. Jurassique, xi. 1e pt. pl. xiii. f. 1, *b*.

Fig. 9. *E. caryophyllatus*, calyx dissected by removal of one radial and the halves of the adjacent radials; shows the radials perforated by canals which run from the axial canal to the apertures on the articular ridge. $\times 2$ diam. After Goldfuss, Petref. Deutschlands, pl. l. f. 3, *d*; see pp. 162–3. The arrangement of the canals harmonizes better with Zittel's account than with that of Carpenter, but I cannot vouch for its correctness. Note slightness of depression for reception of visceral mass as compared with *Phyllocrinus* and *Trigonocrinus*.

Fig. 10. *E. caryophyllatus*, dorsal aspect of calyx, shows small axial canal, but no trace of basals or of radial canals. $\times 2$ diam. After Goldfuss, *op. cit.* pl. l. f. 3, *b*.

Fig. 11. *E. caryophyllatus*, same specimen as in fig. 8, ventral aspect. $\times 3\frac{1}{2}$ diam. After De Loriol, *l. c.* pl. xiii. f. 1, *c*.

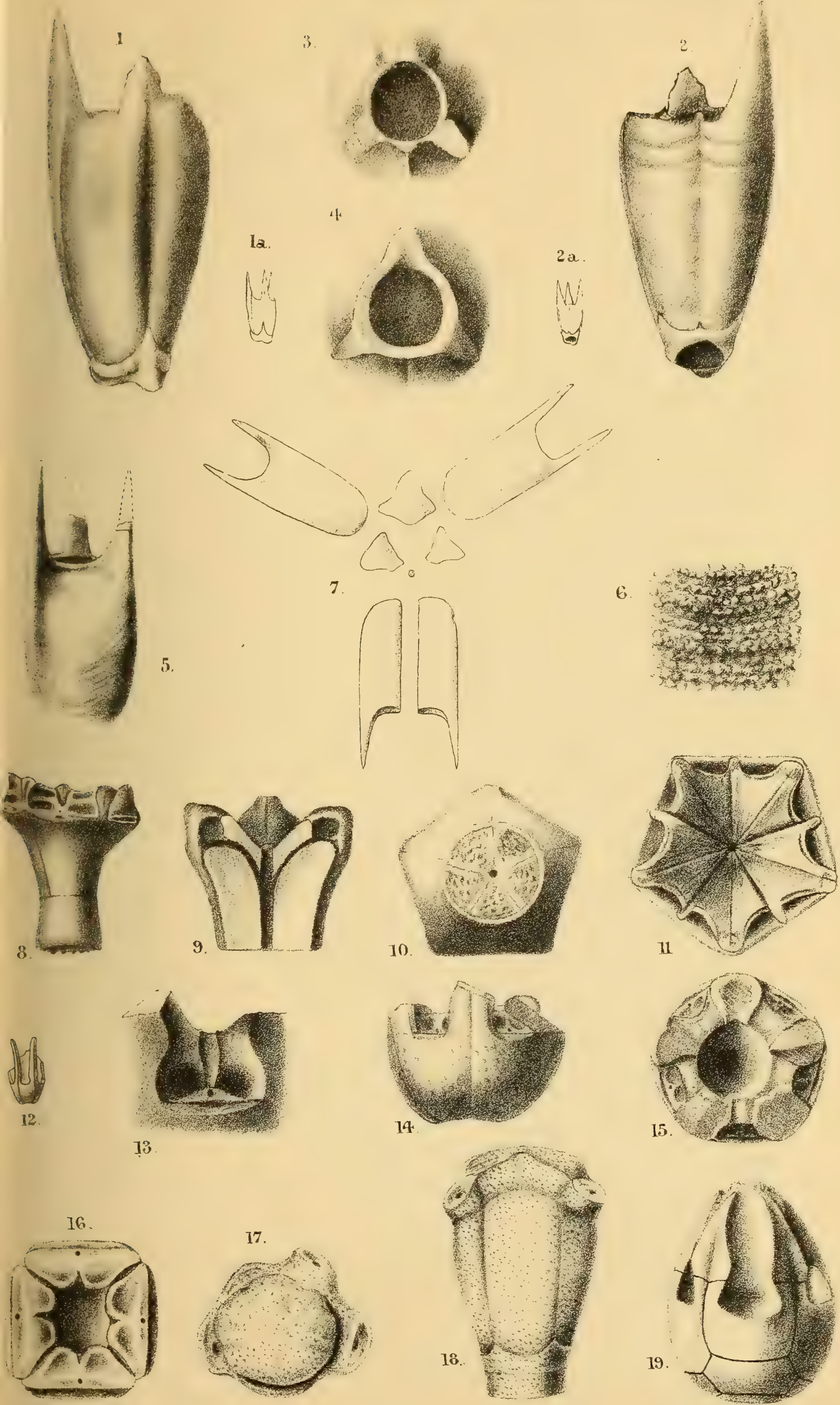
Fig. 12. *Phyllocrinus fenestratus*, Dumortier, sp., calyx of natural size; note long "petals" and constricted notches for arms. After De Loriol, *l. c.* pl. xvii. f. 6.

Fig. 13. *P. fenestratus*, articular facet of radial from another calyx, enlarged; it is less marked than that of *Eugeniacrinus*. After De Loriol, *l. c.* pl. xvii. f, 7, *d*.

Fig. 14. *P. granulatus*, d'Orb. sp., calyx with petals partly broken. $\times 5$ diam. After De Loriol, *l. c.* pl. xviii. f. 1, *a*.

Fig. 15. *P. granulatus*, same specimen as in fig. 14, ventral aspect; note small articular facet and deeper calycal cavity, thus approaching *Trigonocrinus*. $\times 5$ diam. After De Loriol, *l. c.* pl. xviii. f. 1, *b*.

Fig. 16. *Tetracrinus moniliformis*, Münster, ventral aspect of calyx. $\times 4$ diam. After De Loriol, *l. c.* pl. xix. f. 1, *a*.



Parker & Coward del. et lith.

Mintern Bros imp.

TRIGONOCRINUS ETC.

Fig. 17. *Allagecrinus Austini*, E. & C.: "calyx of a specimen in which three radials have distinct articular facets, whilst another has no facet, even of the simplest kind, and there is only an imperfect one on the fifth. Howood, near Johnstone." Ventral aspect. ×24 diam. After Etheridge and Carpenter, Ann. & Mag. Nat. Hist. ser. 5, vol. vii. pl. xvi. f. 9, *b*.

Fig. 18. *A. Austini*. Same specimen as in fig. 17, seen from side. After E. and C. *l. c.* pl. xvi. f. 9, *a*.

Fig. 19. *Haplocrinus mespiliformis*, Goldf., sp., from right anterior ray; for comparison of articular face with that of Eugeniacrinidæ. An arm-joint is seen *in situ* on the right-hand side of the figure. Stringocephalen-kalk, Gerolstein. Brit. Mus. [49136].

Figs. 1, 1 *a*, 2, 2 *a*, 5, 7, and 19 are from my drawings *ad naturam*. Figs. 3, 4, and 6 were drawn, with help of sketches, from the specimens by Mr. M. Prendergast Parker, to whose skill and accuracy I am much indebted. Figs. 8–18 are copied from the authorities cited, with occasional alteration in the direction of clearness.

Discussion.

The President welcomed a new palæontologist to the Society.

Dr. P. Herbert Carpenter accepted without hesitation the Author's reference of this form to a new genus, and assigned it to the same systematic position as did the Author.

He considered his view respecting the basals of *Eugeniacrinus* to be strengthened by what he had heard, and hoped soon to be able to test it by the examination of sufficiently well-preserved material.

The way in which one basal of *Trigonocrinus* is crowded out is peculiar. The arms must have been extremely reduced, and were perhaps attached by suture rather than by articulation. In discussing symmetry the Author appeared to have treated the Crinoids too much as an isolated group, and not as having the general structure of Echinoderms.

Prof. Seeley asked whether it was certain that the specimens were mature forms, and whether it was safe to found a new genus on such limited material. He did not see the necessity for supposing atrophy and fusion following sport. The form, though extremely exceptional, need not be permanent.

The Author replied to Dr. Carpenter that the question regarding the basals was one of the weight of evidence. With reference to the attachment of the arms, the marks of articulation, although *almost*, are not *quite* invisible. As an instance of atrophy, he mentioned the radials of *Triacrinus*. Similar asymmetry occurs in the other classes of Echinodermata; instances among Echinoidea led Haacke to the same conclusions. Everything went to prove the maturity of the forms which he had described.

10. *Note on* Marsupites testudinarius, *v. Schlotheim*, sp.* By F. A. Bather, Esq., B.A., F.G.S., Brit. Mus. (Nat. Hist.). (Read December 19, 1888.)

Confusion has long reigned supreme in the nomenclature of the genus *Marsupites.* The splendid series of specimens in the collection under my care enables me to attempt the restoration of order with some hope of success. A specimen of *Marsupites* was well figured in 'Parkinson's Organic Remains,' ii. pl. xiii. f. 24, and adequately described on pp. 225–229 of that work. Had Parkinson only named his numerous species according to the Linnean method an enormous amount of subsequent confusion, in this and many other cases, would never have occurred. To many of Parkinson's figures names were given by Von Schlotheim; the one now in question he called *Encrinites testudinarius.* Every form hitherto discovered in the English Chalk belongs without a doubt to the same species as Parkinson's specimen. Between absolutely smooth and extremely rugose specimens there are almost as many gradations as there are specimens. It follows therefore that all other names are synonyms of *M. testudinarius.* This solution of the difficulty is undoubtedly the most satisfactory from a scientific point of view: it is also gratifying to know that the specific name we have to adopt is far more sensible and appropriate than any of its successors, and that, unlike them, it does justice to the enthusiastic observer and delightful describer Parkinson.

The synonymy is as follows:—

Marsupites, Miller.

1808. Tortoise Encrinite, J. Parkinson, 'Organic Remains of a former World,' London, ii. 225. Parkinson, referring to "Mr. Lister's paper on the *Radices entrochorum*," says:—"He there gives an engraving of one of the plates of this animal, which he describes only as 'a pentagonous plate embossed with angles.'" The true reference is M. Lister, "A Description of certain Stones figured like Plants, and by some Observing men esteemed to be Plants petrified." Phil. Trans. vol. viii. Tract 100, pp. 6181–6191, London, Feb. 1674. On p. 6190 "Figures of Plates supposed to incrustate divers roots—33. An hexagonous plate embossed with angles." This figure represents the plate of a Carboniferous crinoid. The popular name "Tortoise Encrinite" seems originally to have been applied to *Crotalocrinus rugosus.* Miller (*l. c. inf.* p. 135), and especially Cumberland (*l. c. inf.* pp. 17 and 27), discriminated rightly.

1820. *Encrinites*, von Schlotheim, 'Petrefactenkunde,' Gotha, p. 339; also Nachträge, ii. p. 103 (1823).

* [This paper was read as a second appendix to the Author's memoir on "*Trigonocrinus*," but as it has no direct relation to that paper it has been thought better to print it separately.—Ed. Q. J. G. S.]

1821. *Marsupites*, G. A. Mantell, MS. on Southdown Fossils quoted by Miller, *loc. cit. infra.*

1821. *Marsupites*, Or the Purse-like Animals, J. S. Miller, Nat. Hist. Crinoidea, Bristol, p. 134. Der. *marsupium* a purse, and termination *-ites* fossil.

1824. *Sitularia*, G. Cumberland, on a lithographed figure "printed for circulation among collectors and their friends."

1826. *Sitularia*, G. Cumberland, 'Reliquiæ Conservatæ,' Bristol, p. 26. Der. *situlus* (*sic*), a bucket; the Latin word appears to be *situla*. Nearly always wrongly quoted as *Situtaria*.

1830. *Marsupiocrinites*, H. D. de Blainville, in Dict. des Sci. Nat. Paris, lx. 244, footnote. Der. *marsupium* (!) or *μαρσύπιον* (?), *κρίνον*, and termination *-ites*. The true Greek work is *μάρσιπος*; *μαρσύπιον* occurs in a few Septuagint MSS. as a corruption of the diminutive *μαρσίπιον*. It is a pity that the name *Marsipocrinus* was not adopted from the beginning, as in parallel cases. In 1839, however, J. Phillips, in Murchison's 'Silurian System,' gave the corrupt (or mongrel?) name *Marsupiocrinites* to a distinct Silurian genus; this has been a source of trouble more than once; if we may not take away the name it would at least be advisable to write it correctly, viz. *Marsipocrinus*.

1836. *Marsupium*, L. Agassiz, in "Prodrome d'une Monographie des Radiaires ou Echinodermes," Mém. Soc. Sci. Nat. Neuchâtel, i. (1835), p. 194, gives "*Marsupites*, Mant. (*Marsupium*, Koena—*Marsupiocrinites*, de Bl.)." In 1846 the same writer's 'Nomenclator Zoologicus' quotes "*Marsupium* Koen. Icon. Sect." H. G. Bronn's 'Index Palæontologicus,' 1848, gives the more definite reference to C. König, 'Icones Fossilium Sectiles,' London, 1825. K. v. Zittel, 'Handb. d. Pal.' i. p. 463, also ascribes the name to König. I have been unable to find either this name or any figure of the fossil in any copy of König's work. In H. G. Bronn's 'Klassen und Ordnungen des Thier-Reichs,' ii. Bd. "Aktinozoen," 1860, p. 231, where the reference recurs, there is some confusion between Koninck and König, but I cannot find that L. de Koninck ever used this name. Was Koena a writer? If so, how, when, and where?

All other authors have followed Miller and Mantell in the name of the genus.

MARSUPITES TESTUDINARIUS, v. Schl. sp.

1808. The Tortoise Encrinite, J. Parkinson, Organic Remains, &c., II. 225, Letter xxii. pl. xiii. f. 24 and 30.

1820. *M.* (*Encrinites*) *testudinarius*, von Schlotheim, 'Petrefactenkunde,' p. 339, ref. to Parkinson's f. 24. Der. *testudo*, tortoise.

1821. *M. ornatus*, ornamented purse-like animal, J. S. Miller, 'Nat. Hist. Crinoidea,' p. 136, with plate.

1822. *M. Milleri*, G. A. Mantell, 'Foss. South Downs,' pp. 184–188, pl. xvi. f. 6, 7, 8, 9, 14. A synonym which naturally moved Cumberland to scorn; Miller's description was based on Mantell's own specimens and figures, as Mantell very well knew.

1823. *M. ornatus*, Defrance, Dict. Sci. Nat. xxix. pp. 244, 245.

1823. *M. Mantelli*, Brongniart, Dict. Sci. Nat.; 'Vers et Zoophytes': Planches, Polypiers—Pierreux, xx. f. 5. Name given to figure, which is apparently a copy and represents no new species.

1824. *M.* (*Sitularia*) *triangulariformis*, or triangle-formed Situlite, G. Cumberland, MS. *vide suprà*.

1825. "*M. ornatus*, Mantell," H. G. Bronn, 'System der urweltlichen Pflanzenthiere,' &c., &c., Heidelberg, p. 40, Taf. ii. f. 1.

1826. *M.* (*Sitularia*) *triangulariformis*, G. Cumberland, 'Reliquiæ Conservatæ,' Bristol, pp. 21–28, pl. figs. 30–35.

1830. *M. ornatus*, Blainville, *loc. cit. suprà*.

1835. *M. ornatus*, J. Phillips, 'Geol. Yorkshire,' i. p. 156, pl. i. f. 14.

1836. "*M. ornatus*, Mant.," L. Agassiz, 'Prodrome d'une Monogr.' &c. *suprà cit.* p. 194. He doubtfully refers to it the crinoidal plates formerly known as *Asterias scutata*, *A. stellifera*, and *A. tabulata*; but these probably belong to Palæozoic forms.

1837. *M. ornatus*, G. G. Pusch, 'Polens Paläontologie,' &c., Stuttgart, pp. 9, 10, pl. ii. f. 9. Curiously relegates it to "Ordnung *Blastoides*, Say."

1840. *M. ornatus*, F. A. Römer, 'Versteinerungen des norddeutschen Kreidegebirges,' erste Lief. p. 27.

1850. *M. Milleri*, E. Forbes, in Dixon's 'Geol. Sussex,' 1st ed. p. 343, quite unwarrantably separates this synonym as a species, and applies the name to specimens figured, pl. xx. f. 4, 5, and 9.

1850. *M. ornatus*, E. Forbes, *loc. cit.*, restricts this term to varieties which he does not define, and considers pl. xx. f. 10 a variety of the species so formed.

1850. *M. lævigatus*, E. Forbes, *loc. cit.*, doubtfully founds this new species on a specimen, figured pl. xx. f. 8, in the collection of Mr. Catt (H. Willett, Esq., of Brighton). Der. *levis*, smooth.

1876. *M. ornatus*, F. A. Quenstedt, 'Petrefactenkunde Deutschlands,' erster Abth. iv. Echinodermen, p. 447, Taf. cvi. f. 131–142.

1878. *M. Milleri*, T. Rupert Jones, as editor of Dixon's 'Geol. Sussex' (in Part III., description of the figures in plates x. [46] to xxviii. [64] of the 'Fossils of the South Downs,' p. 456), restricts this name to pl. xvi. [52], f. 6, 7, 8, 9, but gives no reason for the restriction.

1878. *M. ornatus*, T. Rupert Jones, *loc. cit.* p. 456, applies this name to figs. 13 and 14 of same plate. No reason given for this preference.

1878. *M. lævigatus*, T. Rupert Jones, *loc. cit.*, applies this name to f. 15 of same plate, though it in no way agrees with Forbes's original type or description.

Forbes's three names are all the time kept as he left them in the body of the work.

The above is not a complete list of references to the species, but it is believed to contain references to all publications that have affected the nomenclature.

11. *On the* Growth *of* Crystals *in* Igneous Rocks *after their* Consolidation. By Professor John W. Judd, F.R.S., F.G.S. (Read January 9, 1889.)

[Plate VII.]

Contents.

1. Introduction. Secondary Origin of the "Granophyric" structures.

Three years ago, in describing some basic igneous rocks from Scotland and Ireland, I expressed my conviction that a part, at least, of the structures known as *micropegmatitic* and *granophyric* were really of secondary origin*. At the same time, I stated that these structures were so much more clearly illustrated by the intermediate and acid rocks of the same district that it would be well to defer the discussion of the subject till my examination and description of the rocks in question should be completed.

The study of the intermediate and acid lavas (which, in 1874, I grouped under the old English field-name of "felstones") and of their plutonic representatives has occupied much of my time and thought during the last fifteen years. But so numerous and interesting are the problems connected with the wonderful metamorphoses which the minerals of these rocks have undergone, and so singular are the changes which have taken place in the structures of these rocks, that, in spite of a number of visits to the district and much labour in the laboratory, some time must yet elapse before the examination of the chief types and the elucidation of their mode of origin is completed.

In the meanwhile, however, certain discussions which have taken place concerning rock-structures and their significance—especially as a basis of rock-nomenclature and classification—render it desirable that the very definite and unmistakable evidence which I have ob-

* Quart. Journ. Geol. Soc. vol xlii. (1886), pp. 72, 73, pl. vii. fig. 8.

tained concerning the secondary origin of the characteristic structures of the "granophyric" rocks should be placed on record.

The examination of the field-relations of the remarkably varied types of acid and intermediate rocks which occur in the Western Isles of Scotland and the North of Ireland shows that rocks exhibiting the structures known as "granophyric" occur under certain well-marked conditions. The larger, truly granitic eruptive masses usually pass towards their peripheral portions into "granophyres" *; the smaller eruptive bosses and lenticular sheets ("laccolites") of the same rocks exhibit the granophyric character throughout; while the apophyses, and even dykes, proceeding from intrusive masses very often display these same structures, which are, in such cases, not unfrequently developed on a very minute scale. The structures which especially distinguish these *granophyric* rocks are the *micropegmatitic,* the *centric* or *ocellar* structure, the *pseudospherulitic,* the *microgranitic,* and the *drusy* or *miarolitic* structures.

I hope from the study of the remarkably fresh examples of Tertiary rocks, which are in texture intermediate between the granitic and the volcanic types, to illustrate the mode of origin of these various structures, and to show their relations one to another†.

2. Enlargements of detrital fragments of Crystals:—Quartz, Felspar, Hornblende, and Mica.

At the outset of this inquiry I must recall the important and suggestive discovery made by Mr. Sorby, and announced to the Society in his Presidential Address in 1880‡. Mr. Sorby showed that the so-called "crystalline sands" were produced by secondary growths of quartz upon the fragments of quartz-crystals that constitute sand-grains.

Like so many other of this author's discoveries, the new facts then announced have proved wonderfully suggestive and fruitful in new departures of thought.

Mr. A. A Young§, the late Dr. Roland D. Irving||, Mr. Van Hise¶, and other authors in the United States have shown how the structures of sandstones and quartzites may be explained by the application of principles discovered by Mr. Sorby; while Professor

* Throughout this paper I use this term not in the original sense in which it was employed by its author, Vogelsang, but with the meaning which Rosenbusch has proposed to attach to it.

† I may mention, in passing, that the study of the processes of crystallization by which the amorphous silica, replacing the calcic carbonate of chalk-mud, passes into the different varieties of hypocrystalline flint, throws much light upon the changes which have taken place in the ground-mass of igneous rocks. The problem is in this case simplified by the fact that there is only one mineral species involved in the change, namely, quartz; while in the devitrification of the glasses of igneous rocks there is much greater complexity.

‡ Quart. Journ. Geol. Soc. vol. xxxvi. (1880).

§ Am. Journ. Sci. 3rd ser. vol. xxiii. (1881), p. 257, and vol. xxiv. (1881), p. 47.

|| *Ibid.* 3rd ser. vol. xxv. (1883), p. 401.

¶ Bull. U. S. Geol. Survey, no. 8.

Bonney *, the late Mr. J. A. Phillips †, and others in this country have added largely to our knowledge of these interestiug processes. To Mr. Van Hise we are indebted for the further very important discovery that not only portions of quartz-crystals, but fragments derived from felspar-‡ and hornblende- § individuals, when exposed to favourable conditions, undergo, in the like manner, secondary enlargement; while Professor Bonney has shown that similar enlargements of biotite-fragments often take place during a development of foliation in argillaceous rocks ||.

3. Enlargement of Crystals in Igneous Rocks.

That the crystals of many eruptive rocks are surrounded by irregular outgrowths, which are in crystallographic continuity with them, and appear to have been formed subsequently to the crystals themselves, has been recognized by many authors, such as C. Höpfner in 1881 ¶; Prof. G. H. Williams in 1882 **; F. Becke ††, K. Bleibtreu ‡‡, and E. Hussak in 1883 §§; by Dölter and Hussak in 1884 ||||; and by Dr. Max Koch in 1887 ¶¶. These authors, however, appear to have generally regarded the secondary outgrowths to the felspar or other crystals as having been formed while the rock was still in a molten state.

In a very valuable and suggestive memoir, to which I shall more particularly refer in the sequel, Dr. Erasmus Haworth, after describing some very remarkable examples of these outgrowths in the felspars of granitic rocks from Missouri, and discussing all the possible explanations of them, decided in favour of their having been produced *before* the complete consolidation of the mass in which the crystals occur ***.

The first petrographer who seems to have suspected that such outgrowths might have occurred *after* the consolidation of the rock was Dr. F. Becke; and this view is indicated in his very remarkable and thoughtful memoir on the "Eruptivgesteine aus der Gneissformation des niederösterreichische Waldviertels" †††. He appears to have seen that certain secondary growths in hornblende-crystals must have gone on when the rock was in a solid state. In 1887 Mr. Van Hise announced that he had found similar secondary out-

* Quart. Journ. Geol. Soc. vol. xxxv. (1879), p. 666, and subsequent memoirs.
† *Ibid.* vol. xxxvii. 1881, p. 6.
‡ Am. Journ. Sci. 3rd ser. vol. xxvii. (1884), p. 399.
§ Am. Journ. Sci. 3rd ser. vol. xxx. (1885), p. 231.
|| Quart. Journ. Geol. Soc. vol. xliv. (1888), p. 15.
¶ Neues Jahrb. für Min. &c. 1881, Band ii. p. 180.
** *Ibid.* Beilage-Band ii. pp. 605–607.
†† Min. und petr. Mitth. vol. v. p. 147, &c.
‡‡ Zeitschr. d. d. geol. Ges. vol. xxxv. 1883, p. 489.
§§ Sitzungsb. der k. k. Akad. Wiss. Wien (1883), i. Abth.
|||| Neues Jahrb. für Min. &c. (1884), Band i. pp. 18–44.
¶¶ Jahrb. der. k. preuss. geol. Landesanstalt (1887), pp. 77–78 & 98.
*** The Archæan Geology of Missouri (Minneapolis, Minn. 1888), pp. 16–17. This paper also appeared in the American Geologist for May and June 1888.
††† Min. und petr. Mitth. vol. v. (1883), pp. 158, 159, 171, &c.

growths around crystals of both hornblende and augite in certain massive rocks from Michigan and Wisconsin *. In the following year Mr. G. P. Merrill described "Secondary Enlargements of Augites in a Peridotite from Little Deer Isle, Maine," and, like Mr. Van Hise, distinctly asserts that such enlargements must have occurred subsequently to the consolidation of the rock †.

The bearing of Dr. J. Lehmann's important researches on "Contractionsrisse in Krystallen" ‡ upon this question will be discussed in a later page of this paper.

4. Proofs that Growth of Porphyritic Felspars may take place after the Consolidation and the Alteration by Weathering of an Igneous Rock.

In my studies of the Tertiary granophyric rocks of the Western Isles of Scotland and the North of Ireland, I have found abundant evidence that the growth of crystals of felspar and quartz goes on, at the expense of a more or less vitreous matrix, long after the solidification of the rock, and that in this fact we have a satisfactory explanation of the mode of origin of the several "granophyric" structures. I think that it will be desirable at the outset to describe a case in which the evidence of this action appears to me to be so clear as to place it altogether beyond question.

The rock in which the illustration occurs is one belonging to a group that, as I shall hereafter show, is very frequently represented among the lavas of the district; in chemical composition it lies on the borders of the intermediate and basic groups, and would be designated by French petrographers a "Labradorite;" in fact, it corresponds very closely indeed with the Icelandic labradorites so well described by M. Réné Bréon §.

As it is manifestly inconvenient, however, to employ the same term both for a rock and for a mineral, I would suggest that the rocks in question should be called "labradorite-andesites." They consist of large crystals of a lime-soda felspar, closely corresponding to labradorite (or sometimes to a felspar intermediate between that species and anorthite), scattered through a glassy base containing microlites of felspar, augite, and magnetite; olivine is usually so rare in the rock that we can regard it only as an accessory constituent. I shall show that, as the result of certain alterations, this Tertiary rock assumes the characters which are universally accepted as distinguishing the "labradorite-porphyrites," of which the well-known verde-antique and Lambay-Island porphyries are such excellent examples. In Iceland, however, these rocks are found in

* Am. Journ. Sci. 3rd ser. vol. xxxiii. (1887), p. 385.

† *Ibid.* vol. xxxv. (1888), p. 488–496.

‡ Zeitschr. f. Kryst. Bd. xi. (1886), pp. 608–612.

§ Notes pour servir à l'étude de la Géologie de l'Islande et des Iles Færœ (1884). I am greatly indebted to M. Bréon for supplying me with an interesting series of these rocks for comparison with those which I am studying in our own country.

a perfectly fresh condition, while in Mull and other parts of the Western Isles they may be traced undergoing certain changes due to both deep-seated and surface-action, and also exhibiting interesting examples of the so-called *propylitic* modification.

It is in a labradorite-andesite from Dun da Ghaoithe (Dun-da-gu) in Mull, a locality where rocks of this type are admirably displayed, that the enlarged crystals which I propose to describe occur. The principal minerals in the rock are large, idiomorphic felspar-crystals (which are shown by their extinctions, their specific gravity, and their flame-reactions to approximate to labradorite), and there are also a few individuals of augite and magnetite. Between these crystals, glass is frequently caught up, sometimes in angular portions, giving rise to the appearance called by Professor Rosenbusch "intersertal structure." The glassy matrix, in many places, is seen to have undergone much change, while the crystals are comparatively fresh and unaltered.

On close examination, the felspar-crystals in the rock-sections are found to exhibit remarkably irregular and ragged outlines; and a minute scrutiny reveals the fact that each crystal has a central core, which shows the rounded and sometimes corroded forms so frequently seen in the porphyritic crystals of rocks. When viewed between crossed nicols, the distinction between the central core and the irregular fringe surrounding it becomes very striking.

Looked at very carefully, the portion lying in the centre of each crystal is seen not only to exhibit corroded surfaces and glass-enclosures, but to be traversed by cracks, to contain bands of secondary inclusions, and to present planes of decomposition (kaolinization) which do not exist in the outer clear and transparent fringe In most cases the outer fringe is quite subordinate to the mass of the crystals (see Pl. VII. figs. 1, 2); but in a few instances the outer fresh portion is equal in area, as seen in thin sections, to the altered and more or less rounded core which it encloses (see Pl. VII. fig. 3). Occasionally the enveloped crystal can be seen to have undergone actual fracture; and in these cases, the cracks in the fractured crystals are found to be filled up, and the portions of the crystal to be cemented together by felspar-material, which extinguishes with the surrounding mass and not with the central core itself (see Pl. VII. fig. 2). It is a very significant circumstance that the crystals have only undergone enlargement where they are in contact with the glassy matrix, and that where other crystals lie against them, all growth has been prevented.

5. Changes in the Composition of the Outer Zones of Felspar-crystals during their Growth.

When studied by polarized light, these felspar-crystals exhibit one very important difference from similarly enlarged quartz-crystals. The crystallographic continuity of the inner and outer portions of the crystals is shown by the way the twin-planes sometimes pass from the one to the other (see Pl. VII. fig. 2); but the inner and

outer portions of the crystal *do not extinguish simultaneously* when the section is rotated between crossed nicols. On the contrary, in rotating the crystal, after the position of extinction of the internal core has been passed, a dark zone of extinction makes its appearance around the central mass, and, as rotation goes on, this dark zone passes slowly and gradually outwards through the surrounding fringe (see Pl. VII. fig. 3).

Nothing can be more striking and suggestive than this beautiful phenomenon, which it is possible to observe and verify in the case of many of the crystals in this very interesting rock.

I think there cannot be any real doubt as to the true explanation of the remarkable appearances which I have been describing.

The more or less decomposed character of the glassy ground-mass in these rocks, as compared with the crystallized minerals, shows that the vitreous part is in a less stable condition than the crystalline. That long after the consolidation of the rock the crystals grew outwards irregularly, at the expense of the surrounding glassy magma, is clear; this being shown by the fact that where two crystal faces are in juxtaposition without the intervention of glassy material, no exterior fringe is formed. The phenomenon which these particular crystals exhibit—and which it is especially important to bear in mind—is that they have not only been developed before the secondary outgrowths have been formed around them, but that they have suffered a considerable amount of injury and alteration from the action of mechanical and chemical forces. This is especially well shown when the junctions of the old and the new portions of the crystal are studied with high microscopic powers.

On the other hand, it can be proved in the same way that the period since the development of the outer fringe of new material has been sufficient for the formation of new cracks and bands of enclosures, which traverse both the old and new portions of the crystals alike. In most cases the twin-lamellæ pass from one portion to the other; but whether this twinning was developed before or after the outgrowths were formed can only be proved in the cases (which sometimes occur) when incipient kaolinization has taken place along the twin-planes, which are thus shown to have been solution-planes, before the outward growth took place (see Pl. VII. fig. 1).

In a few instances, I have found proof that secondary twinning has been developed in the fringe of new material, but does not extend into the old nucleus.

The remarkable behaviour of the zone of extinction is well worthy of study and consideration. The existence of zoned plagioclastic felspars with areas giving different extinction is well known; and in most of these the more basic portions form the centre and approximate to the Anorthite-extreme, while the outer zones are successively more acid in character and approach towards the Albite-limit. But, in nearly all such cases the successive zones are clearly and sharply marked off from one another, and they not unfrequently exhibit numerous solid and liquid inclusions, or other indications that the growth of the crystal had been arrested at successive stages, and

that, after an interval, growth had been resumed under somewhat different conditions. In the felspars I am now describing, however, the zone of extinction passes gradually, and *without any kind of break whatever*, from the original central core through the secondary peripheral fringe. Taking note of the amount of rotation required to produce extinction in different zones in the cases of crystals exhibiting the largest periphery, I have found it to be such as to lead me to conclude that some crystals with a composition between labradorite and anorthite have an irregular fringe which, as we pass outwards, corresponds to every intermediate stage through the Andesine and Oligoclase series, and sometimes approaches, if it does not actually reach, the Albite-limit *.

Nowhere, I think, could we have a more convincing illustration of the truth of Tschermak's beautiful theory of the felspars. We find absolute evidence of the *perfectly gradual change* of the optical characters of these crystals as we follow them from the original central mass through the portions representing consecutive additions to it.

Nor is the explanation of the facts observed difficult. When the rock, by cooling, assumed the solid state, the stable well-formed porphyritic crystals were separated by portions of vitreous material, this vitreous material consisting of unstable mixtures of various silicates of lime and the alkalies.

We must never forget that in the deep-seated rocks—and it is in such only that these and similar changes seem to occur—the whole mass, crystals and base alike, must be permeated by liquids and gases; and chemical reactions (like those involved in the process of schillerization) can readily take place.

The tendency of the more basic minerals to separate from a magma before the more acid ones, which has been so clearly pointed out by Rosenbusch and other authors, leads to the gradual exhaustion of the lime; and as the proportion of this ingredient in the limited portion of magma that can be drawn upon is diminished, more and more of the alkaline constituent must be taken up by the growing felspar, which thus gradually passes from a basic lime-felspar towards an acid alkali-felspar. At last little else than the silica may be left, and, as we shall see hereafter, this tends to crystallize as quartz, sometimes simultaneously with, and sometimes after the whole of the felspar has crystallized.

Prof. Lagorio, in a very useful and painstaking investigation, has endeavoured to apply the important results obtained by the late Dr. Guthrie on "Eutectic Compounds" to the explanation of the

* M. Michel-Lévy is of opinion that the same phenomenon would result if the different zones of the felspars, instead of consisting of homogeneous materials of different chemical compositions, were variously built up of "submicroscopical" (*i. e.* ultramicroscopical) twin-lamellæ arranged on the pericline and albite types. For the purpose of my argument it is not of great importance which theoretical view of the molecular structure of the felspars is accepted. It is sufficient to have demonstrated that in these cases the angle of extinction varies gradually and progressively as the crystal grows at the expense of the residual glass.

nature of the glassy base which is found in igneous rocks *. An admirable discussion of Lagorio's results has been given by Mr. Teall †, who has supplied further illustrations of the subject. The interesting analyses of Lagorio show very clearly that the glassy magmas of igneous rocks are just of such a composition as to permit anges of the kind I have been describing to take place in them.

6. The peculiar Conditions which have given rise to the Phenomena observed in the particular case now described.

It may not unreasonably be asked why the felspars in this particular rock should exhibit this phenomenon in such a very marked and unmistakable manner; and it may fairly be objected to the views I have expressed that, if the phenomenon of crystal-growth be a common one, it ought to be more frequently and easily traced. To this objection I think that I am able to give a complete reply.

Careful study of a large number of cases convinces me that this growth of felspar-crystals at the expense of the surrounding unstable magma is of very frequent occurrence in rocks which have been deep-seated at any part of their history. A very interesting series of rocks which I have received from New South Wales by the kindness of my friend T. Edgeworth David, F.G.S., shows that the secondary growth of a felspar may even take place after the advanced kaolinization of the original crystal.

But in the great majority of cases, these secondary outgrowths are undoubtedly formed while the original crystal is still fresh and unaltered, and thus it is not easy to demonstrate that the growth has gone on after the surrounding magma has become solid.

The clearness of the evidence in the particular case described is the result of the circumstance of the *alteration of the felspar* before its growth recommenced; and of this peculiarity I am able to give a very simple explanation. The labradorite-andesite in which these crystals occur is one of the old series of "felstone"-lavas which I described in 1874 as belonging to the earliest period of eruption in the Mull volcano. The lava-stream had been exposed to denudation and weathering action for long periods of time, sufficient to allow of the mechanical injury and partial kaolinization of the felspar.

Subsequently, this old lava was buried to the depth of several thousands of feet by the later out-welling of basaltic and other lavas—the consequence being that the mass was placed under just the conditions which are favourable to the renewed growth of the felspar-crystals. In the presence of these conditions—pressure, heat, and the free passage of liquids and gases through the solid rock-mass—the crystals already corroded by their surrounding magma, and altered by surface-agencies, renewed their youth and recommenced their growth. But, depending, as they did, for the supply of fresh material on the limited volumes of glass surrounding them, the remarkable change in composition, as the lime was extracted from the glass faster than the soda, was brought about.

* Min. u. petr. Mitth. viii. (1887), p. 421.
† 'British Petrography' (1888), pp. 391–401.

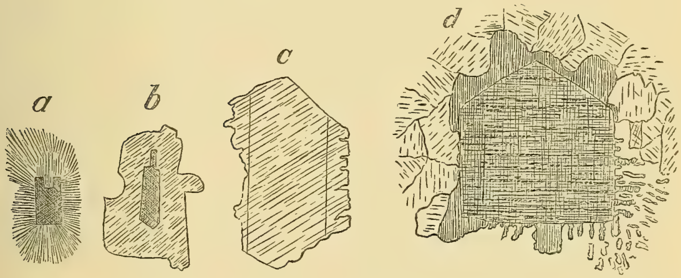
7. Relation of these facts to Dr. Lehmann's theory of the Origin of Perthite-structure, and other recent researches.

There are some recent researches that give very considerable support to the views I have been advocating. Prof. Lehmann has shown that, on heating and cooling, crystals undergo contraction along planes which he calls "Contractionsrisse." These "Contractionsrisse" he shows are sometimes planes of cleavage and at other times gliding-planes. He refers the beautiful structure known as perthite and microperthite—so commonly seen in micorocline—to the separation of the orthoclase-crystals along their "Contractionsrisse," and the deposition of secondary albite in the fissures thus formed.

In this case we have an example of an action strikingly similar to that which I have been describing *.

Dr. Erasmus Haworth, in the very interesting communication to which I have already referred, gives descriptions and drawings of a striking series of appearances which he detected in certain Missouri granites. He shows that idiomorphic crystals of felspar sometimes exhibit enlargements similar to those I have been describing (figs. *b* and *c*) and at other times a pseudo-spherulitic fringe (fig. *a*).

Orthoclase-Crystals from Granite of Missouri.
(After Dr. E. Haworth.)



In *a* the crystal is surrounded by a pseudo-spherulitic border; in *b* and *c* there are enlargements with continuous cleavage; and in *d* "the idiomorphic orthoclase is partly surrounded by a secondary growth, and partly by a micropegmatite in which the felspar is attached to the original crystal and oriented with it."

Still more remarkable are the cases which he cites of idiomorphic orthoclase, surrounded by secondary outgrowths, which in parts exhibit all the characters of a true micropegmatite, the central

* "Ueber die Mikroklin- und Perthit-Structur der Kalifeldspathe und deren Abhängigkeit von äusseren z. Th. mechanischen Einflüssen." Jahres-Bericht der schles. Gesellschaft für vaterländische Cultur, für 1885, Sitzung vom 11 Feb., also in same Journal, p. 92, and 1886, pp. 119–120. See also Zeitschr. f. Kryst. Bd. ii. 1886, pp. 608–612.

Dr. Lehmann informs me that he hopes soon to publish full details, with illustrations, of these very important researches.

crystal and the outgrowths extinguishing together (fig. *d*). Dr. Haworth's illustrations of these phenomena are so excellent that I prefer to reproduce them rather than to select from numerous similar cases that have come under my own observation. It is true that Dr. Haworth does not take the view that these secondary outgrowths were formed after the solidification of the mass, but rather that "in the process of cooling the felspar-crystals were formed and floated about in the magma for some time, as the porphyritic felspars do in the magma of a porphyry" *. After the proofs I have now given that such secondary growths can and do take place in a rock-mass, long after it has become solid, the objections raised by Dr. Haworth to this explanation disappear.

When it is remembered how crystals are developed in the midst of solid rock-masses, during contact-metamorphism, this growth of crystals in solid igneous rocks ought to occasion no surprise.

My friend Prof. G. H. Williams—in whose laboratory have been carried on so many researches having an important bearing on the questions discussed in this paper—has in his various memoirs and also in private correspondence called my attention to phenomena which seem at first sight to be inconsistent with the theory of schillerization which I have propounded. He refers to the case of felspar-crystals which contain a central mass filled with inclusions, but in which an outer zone is seen quite free from such inclusions.

I have studied many such cases, and in some of them have been able to prove that the clear outer zone is really a secondary outgrowth to the crystal. I have found what I think is indisputable evidence that the outer portion of a crystal may be removed under one set of conditions, and that under other conditions its growth has recommenced again; just as a crystal of alum would behave if first taken from a saturated solution and put into warm water, and then after a certain interval transferred again to the original or some other saturated solution of an alum.

I must postpone to a future occasion the discussion of the exact nature of the operations which result in the formation of the different varieties of micropegmatitic, centric, pseudospherulitic, and miarolitic structures, respectively. In all these cases, I believe, I shall be able to show that, in vitreous or imperfectly crystallized material, the instability which exists has permitted the formation in the solid rock of outgrowths to preexisting stable crystals.

I shall show that there is every gradation from a glassy ground-mass to one characteristic of the so-called granophyric rocks, and prove that the characteristic structures of those rocks must be attributed to secondary rather than to primary devitrification. The cavities found in the "miarolitic" or drusy granites—which are so difficult to account for on any other hypothesis—will be shown to be fully explained by the contraction which a more or less glassy ground-mass has undergone during devitrification.

* *Loc. cit.* pp. 15–16.

8. Bearing of these considerations on the problem of the Origin of Foliation in the Metamorphic Rocks.

It is scarcely necessary to point out the important bearing of this principle of the growth of crystals—and especially of felspar-crystals—in solid rock-masses upon the great question of the origin of foliation in rocks, a question in the discussion of which the Fellows of this Society have taken so prominent a part.

That, as the result of contact-metamorphism, many well-defined mineral species are developed in the midst of solid rocks, the crystals growing at the expense of and deriving their materials from the surrounding detrital fragments, has long been recognized. These phenomena find many beautiful illustrations in the so-called "spotted schists." I hope to be able to show, on a future occasion, how large a part a similar action plays in producing the characteristic structures of many fresh and apparently unaltered igneous rocks.

The founders of the theory of dynamo-metamorphism—Scrope and Darwin—very clearly perceived that in the study of igneous rock-masses which have been subjected to movements and internal stresses, we find alike the clearest analogies and the simplest and most readily studied examples of the processes which go on during the production of foliation in rocks. Those who have done most towards establishing the theory on its present firm basis, by tracing with the aid of the microscope the *actual* changes which the minerals of rocks undergo while the development of foliation is in progress—and I especially refer to the beautiful researches of Lossen and Lehmann and those of students of petrography who, like Dr. Reusch in Scandinavia, Prof. Williams in America, and Mr. Teall in this country, have sought to follow in their steps—have skilfully and patiently pursued the same methods.

Charles Darwin was able to show, by the aid of a pocket-lens and blowpipe only, that in a holocrystalline lava in the Island of Ascension which had been subjected to powerful internal mechanical stresses, the felspar, augite, and magnetite had separated from the glassy mass in distinct and parallel folia *. He clearly perceived, what some in more recent years have quite failed to realize, that mechanical force *per se* is wholly incompetent to produce a true foliation in rocks; but that the mechanical force becomes really effective by determining and controlling the operations of chemical affinity and crystallization; and it is by these that the metamorphoses of the minerals in rocks are brought about which result in the development of the foliated structure.

The more carefully these metamorphoses of the minerals in rocks are studied, and the more clearly it is perceived that the whole structure of deep-seated rocks may undergo a complete transformation, during such metamorphoses of their constituent minerals, the less difficulty will be felt in accepting the teachings of Scrope and

* Darwin's 'Volcanic Islands,' published in 1844, p. 56 (p. 64 of reprint issued in 1876). I have studied Darwin's original specimens with the microscope, and can confirm the wonderful accuracy and acumen of his researches.

Darwin, which have in recent years received such valuable illustration from the admirable researches of Lossen, Lehmann, and many other petrographers.

EXPLANATION OF PLATE VII.

Outgrowths to felspar-crystals in labradorite-andesite, Dun da Ghaoithe, Isle of Mull.

Fig. 1. Crystal of felspar as seen, magnified 25 diameters, by ordinary light. The contrast between the original crystal with its numerous cracks (some of which show incipient kaolinization along their sides) and the comparatively fresh and irregular outgrowths of secondary origin is very clearly seen.

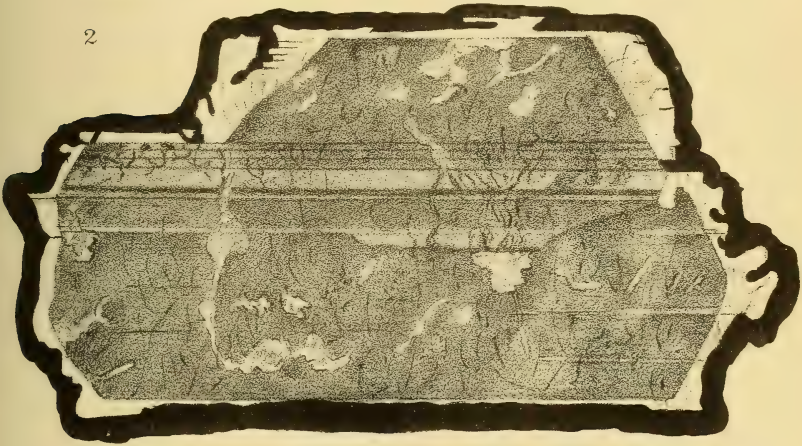
2. The same crystal as seen with crossed nicols. The difference of the extinction-angle between the central core and the surrounding secondary fringe causes the latter to remain light, while the former, except where traversed by twin-lamellæ, is dark. It is very noticeable that newly deposited felspar-substance filling the cracks of the original crystal extinguishes with the outer fringe.

3. Another crystal of felspar as seen magnified 75 diameters. The great extent of the outgrowths, as compared with the original rounded grain of felspar, is very striking; as is also the very irregular development of the secondary fringe. The crystal is represented as seen with crossed nicols, the stage being rotated into such a position that the zone of extinction, traversing the portions of the crystal which have the same chemical composition, lies in the midst of the secondary outgrowth. As the stage is gradually rotated this zone of extinction is seen to pass slowly and progressively outwards, *without any kind of break*, till it reaches the most distant apophyses. Some of these last must have a composition very closely approximating to that of albite.

1

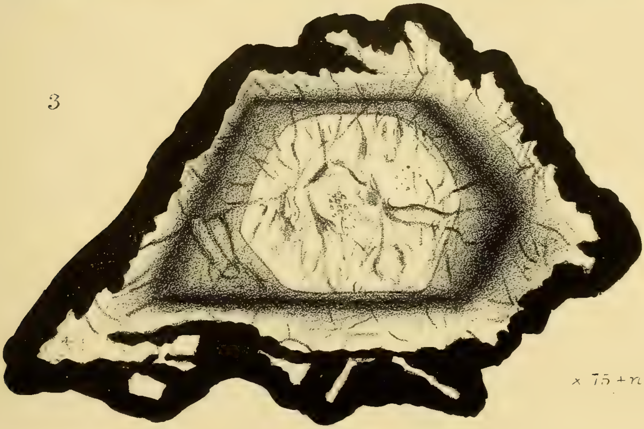
× 25

2



× 25 + nic.

3



× 75 + nic.

Parker & Coward, lith.

West, Newman & Co. imp.

SECONDARY OUTGROWTHS TO FELSPAR-CRYSTALS IN LABRADORITE-ANDESITE. I. OF MULL.

12. *The* Tertiary Volcanoes *of the* Western Isles *of* Scotland. By Professor John W. Judd, F.R.S., F.G.S. (Read January 9, 1889.)

Contents.

I. Introduction.

In the year 1874 I communicated to this Society the results of my studies concerning the Tertiary and Older Volcanic rocks of Western Scotland, and their relations to the Secondary strata with which they are so intimately associated *. The very generous manner in which the memoir dealing with those subjects was received by this Society—and especially by those who were at that time the leaders of geological thought in this country—can never be forgotten by me. Such a reception lays upon the author of a memoir certain very obvious responsibilities. In the event of serious and fatal errors being indicated in his observations or reasoning, it is clearly his duty to come forward and frankly withdraw the statements to which this Society has given such wide currency. It is equally incumbent upon him, should his premises and conclusions be openly challenged on what seem to him to be insufficient grounds, to undertake the task of re-examining and, if necessary, of defending his views.

It may not perhaps be out of place to remark that my work in Scotland, to which were devoted five years of heavy labour and careful research, was one that taxed to the full the powers of a private individual. It involved the examination of the physical relations and the discussion of the palæontological characteristics of the whole of the rocks of the Highlands between the Old Red Sand-

* Quart. Journ. Geol. Soc. vol. xxx. (1874), pp. 220–302.

stone and the Glacial deposits. Of these formations, it may be remembered that the strata of Carboniferous and Cretaceous age had remained wholly unrecognized before my studies commenced; while, with respect to the age and relations of the several members of the Triassic and Jurassic systems, as well as concerning the great masses of igneous rocks, very confused and inaccurate ideas prevailed. I may add that the country in which these rocks are exhibited was at the time quite destitute of any reliable maps upon which the observations of the geologist could be accurately recorded. Under these circumstances, I may claim that my work should be judged, I will not say with indulgence—for such I do not ask—but with that fair consideration which pioneer labour in our science has always received at the hands of those who constitute this Society. If the great outlines of the subject were faithfully traced, and the true bearings of the leading facts were rightly appreciated, I submit that this was all that could be expected under the circumstances, as it was certainly all that I hoped to be able to accomplish.

During the last fifteen years it has been my endeavour to fill in the sketch, of which the outlines had, I believe, been accurately drawn, and to correct or supplement those points of detail upon which my information was defective; and I trust that, in doing so, I have shown no reluctance to confess omissions or mistakes of which I may have been guilty.

My original intention had been to confine the series of memoirs on "The Secondary Rocks of Scotland" to the description of the stratified deposits; but when I came to study the relations of these to the igneous masses in the Western Isles of Scotland, I found that such very serious errors had been made in the interpretation of the latter, as to necessitate the preparation of a general sketch of what appeared to me to be their true relations. In justification of this course, I am compelled, in consequence of statements that have recently been made, to refer to the literature bearing upon the subject which was in existence when I commenced my task in 1871.

II. Views which were maintained previous to 1874.

The very able geologist, mineralogist, and chemist, Dr. John Macculloch, early in the present century, gave a most admirable account of the igneous rocks of the Western Isles of Scotland. He clearly perceived and distinctly pointed out the fact that the granites and gabbros of the area constitute, with the felsites and basalts, one great contemporaneous series of rocks—a series which, as a whole, overlies and is younger than the Secondary strata of the district. He noticed the *apparent* interbedding of these igneous rocks with Oolitic and Liassic strata; but he clearly demonstrated that in all such cases the igneous masses are really intrusive in, and therefore younger than, the Jurassic rocks *.

* Macculloch's observations were published in the First Series of Transactions of this Society, and afterwards in fuller detail in his classic 'Description of the Western Isles of Scotland,' 3 vols. with plates and maps (1819).

In 1851 the Duke of Argyll brought forward the evidence of the plant-remains of Ardtun, which Professor Edward Forbes correctly interpreted as proving the Tertiary age of the basalts with which they were intercalated *.

Unfortunately, as the result of a hasty yachting-cruise in the Western Isles, Prof. Forbes at the same time suggested, though with much reserve, that the basalts of Loch Staffin might possibly be contemporaneous with the associated Jurassic strata †.

In the year 1858 Dr. Archibald Geikie published his first memoir dealing with the igneous rocks of the Hebrides ‡. In this memoir the most serious charges were brought against Dr. Macculloch, his veracity was impeached, and an attempt was made to throw discredit upon the whole of his geological observations §. The author, as the result of his own studies, maintained that the granitic rocks of central Skye belong to two different periods. He noticed the peculiar rocks of Cnoc nam Fitheach, but failed to recognize that they are masses of volcanic agglomerate.

The same author, in 1861, published a paper devoted to the full consideration of "the Chronology of the Trap-Rocks of Scotland" ||. This memoir, which is illustrated by a map and section, aims at substituting for the conclusions of Macculloch the following propositions :—

(1) The gabbros ("hypersthene-rock") of Syke are of metamorphic origin and of *Laurentian* age.

(2) The great mass of the igneous rocks of the Western Isles are of *Oolitic* age, and this is also the age of the numerous dykes traversing Southern Scotland and the North of England.

(3) In Mull, however, there occur certain basalts which were erupted during the *Tertiary* period.

In 1865 the same author published a work ¶ in which the Laurentian age of Skye gabbros, and the Oolitic age of the great mass of the basalts of the Western Isles of Scotland, is still maintained.

Two years later appeared a memoir from the same hand, in which it is admitted that, so far as Mull is concerned, the reference of the great masses of basalts to the Oolitic period was a mistake, and that they really belong to the Tertiary **.

Still later, in 1871, a very admirable account of the geology of the Island of Eigg, by the same author, was preceded by a statement of his general views concerning the relations and age of the igneous rocks of the Western Isles of Scotland. It must be pointed out that in this general statement, while the Tertiary age of all the basaltic

* Quart. Journ. Geol. Soc. vol. vii. (1851), pp. 89 and 103.

† *Loc. cit.* p. 108.

‡ *Ibid.* vol. xiv. (1858), pp. 1–23.

§ *Loc. cit.* pp. 3–4. I have shown on a former occasion that these very grave charges against one of the great pioneers in British Geology are entirely groundless. See Quart. Journ. Geol. Soc. vol. xxxiv. (1878), p. 700 (footnote).

|| Trans. Roy. Soc. Edinb. vol. xxii. (1861), pp. 633–753.

¶ 'The Scenery of Scotland viewed in connection with its Physical Geology,' with a Geological Map (1865).

** Proc. Roy. Soc. Edinb. vol. vi. (1867), p. 71.

rocks is maintained, no reference is made, either in the text or in the table given, to the gabbros of Skye, which, as we have seen, had always been held by the author to be metamorphic rocks of Laurentian age. The gabbros of Mull are doubtfully referred to as being basaltic lavas which have undergone metamorphism *.

In the same year, 1871, Prof. Zirkel published his admirable "Geologische Skizzen von der Westküste Schottlands" †, containing a very excellent account of the petrology of the district. In treating of the age and relations of the various rock-masses of igneous origin, he unfortunately took Dr. Geikie as his guide rather than Dr. Macculloch; and as Zirkel's work has become classical, owing to the excellence of his petrographic descriptions, the erroneous representations of the relations and ages of the igneous rocks given in it have been extensively copied and very widely circulated. Even at the present day most foreign manuals of geology continue to reproduce these admittedly erroneous statements concerning the age and relations of the igneous rocks of Western Scotland.

Such was the state of information upon the subject when I took up the study of the district, and after several years of continuous work upon it, published my paper of 1874. While acknowledging the very great assistance I had derived from the writings of Dr. Macculloch and Professor Zirkel, I was compelled to state that my observations led to conclusions at utter variance with those arrived at by Dr. Geikie, as indicated above ‡.

After an interval of nearly fifteen years, the last-named author has issued a memoir § in which, while abandoning his old views and adopting in almost every particular the conclusions I had announced in 1874, he lays great stress on certain minor points of difference between us, and offers a different theoretical explanation of the facts from that which I had proposed.

My object, in the present memoir, is to direct attention to the following subjects:—

First. The conclusions of my paper of 1874 which find support in the observations since made by Dr. Geikie and other members of the Geological Survey—the results of which are given in the memoir referred to;

Secondly. The observations which seem to contradict or qualify the conclusions at which I arrived in 1874; and

Thirdly. The alternative theory which has been proposed to explain the general relations of the rocks of the district.

III. Conclusions announced in 1874, which have been confirmed by subsequent Observations.

I cannot do better than to state, as succinctly as possible, the chief propositions the truth of which I endeavoured to establish in my

* Quart. Journ. Geol. Soc. vol. xxvii. (1871), pp. 282–283.
† Zeitschr. d. d. geol. Gesellsch. Bd. xxiii. (1871), pp. 1–124.
‡ Quart. Journ. Geol. Soc. vol. xxx. (1874), p. 223 (footnote).
§ "The History of Volcanic Action during the Tertiary Period in the British Isles," Trans. Roy. Soc. Edinb. vol. xxxv. pt. 2, pp. 21–184.

previous memoir, and point out how far these have been substantiated, modified, or refuted by the work of the Director-General of the Geological Survey and of different members of his staff.

By far the most important of the results of my study of the igneous rocks in the Western Isles of Scotland was the establishment of the true relation to one another of the so-called *Plutonic* and *Volcanic* rocks of that district. Darwin had long before shown similar relations to exist between the granites and lavas of the Andes; while Jukes and other writers had insisted upon the gradation of highly crystalline into glassy rocks as being on *à priori* grounds probable. But the demonstration that in a particular area there exist the data for illustrating the complete transition of granitic into glassy rocks, both in the acid and basic series, has been regarded not only in this country, but by many foreign geologists, such as Suess, Reyer, and Dana, as marking a distinct and important addition to geological knowledge.

A. *The Relations between the Plutonic and the Volcanic Rocks of the Western Isles of Scotland.*

My conclusions on this subject may be briefly summarized as follows:—

There exist in the Western Isles of Scotland true Plutonic rocks (*granites* and *gabbros*) exhibiting a perfectly holocrystalline structure, and it is possible to trace every gradation from these through different microcrystalline and cryptocrystalline rocks into truly vitreous ones (*pitchstones* and *tachylytes*). The distinction between Plutonic and Volcanic rocks—however convenient and necessary it may be in practice—is a purely arbitrary one, some lavas being more highly crystalline than certain portions of intrusive masses; for the degree of crystallization in each case is determined by the conditions under which the originally molten masses have been placed. (Quart. Journ. Geol. Soc. 1874, pp. 233–248).

I need not remind the members of this Society that these views—though they were very warmly accepted by many fellow-workers in this country—were received in many quarters abroad with much opposition and even with ridicule. Equally unnecessary is it to refer to subsequent papers in which I endeavoured to support and defend my conclusions by a reference to other areas, or by giving more detailed descriptions of some of the Scottish rocks *.

Within the last few years, however, a number of foreign geologists have described relations very similar to those which I pointed out in Scotland as existing between the Plutonic and Volcanic rocks of other areas; and the conclusions which they have arrived at are almost identical with my own. This is especially the case with

* See especially the Memoir "On the Ancient Volcano of Schemnitz, Hungary," Quart. Journ. Geol. Soc. vol. xxxii. (1876), p. 292, and 'Volcanoes, what they are and what they teach' (1881), pp. 53–56; also Quart. Journ. Geol. Soc. vol. xli. (1885), pp. 354–418, and vol. xlii. (1886), pp. 49–97.

Messrs. Arnold Hague and J. P. Iddings in regard to the rocks of the Washoe district *; with Signor B. Lotti in respect to the Elba rocks †; and with Prof. A. Stelzner in respect to the rocks of the Andes ‡, previously studied by Darwin.

It is very gratifying to me to find that in the memoir recently published there is the most unreserved and complete acceptance of the conclusions announced by me in 1874; and this acceptance is of the greater significance when we bear in mind the great difference in the views previously maintained by the author of the memoir. The studies of the Director-General of the Geological Survey and of different members of his staff have afforded evidence of the most unmistakable character that gabbros graduate insensibly into dolerites, and dolerites into basalts, while the last-mentioned rocks pass into tachylytes (Trans. Roy. Soc. Edinb. 1888, pp. 122–124); they are equally satisfied with the proofs that true granites merge insensibly through various intermediate forms, called "granophyric" by Rosenbusch, into the acid lavas and pitchstones (*loc. cit.* pp. 145–150); not less unhesitating is the testimony of the recently published memoir to the relation between the textures of the several types of igneous rocks in the Hebrides and their geological positions. It is maintained that the finer-grained varieties occur in the smaller intrusive masses and in the peripheral portions of larger ones (T. R. S. E. 1888, pp. 120–147, &c.), and that in many massive lava-streams we find rocks of more highly crystalline character than in some of the smaller intrusive dykes and sheets (*loc. cit.* pp. 77, 117, &c.). Finally the conclusion is stated that the differences between the gabbros and the basic lavas, and between the granites and the more acid ones, must be ascribed to the circumstance that the Plutonic rocks have consolidated at great depths beneath the surface, and therefore slowly and under great pressure, while the lavas cooling at the surface have not been subjected to these conditions (*loc. cit.* p. 140 &c.). These passages may be compared with the general account of the relations of the igneous rocks of the district (Q. J. G. S. 1874, pp. 233–248).

B. *The Existence of five Great Centres of Eruption, with many minor and scattered Vents in the Western Isles of Scotland.*

My conclusions on this subject, as given in 1874, may be stated briefly as follows:—

There exist at five well-marked centres—namely, Mull, Ardnamurchan, Rum, Skye, and St. Kilda—clear evidence that eruptive action on a grand scale took place. This evidence is as follows:—

(1) There occur enormous masses of lava, of both acid and basic

* "On the Development of Crystallization in Igneous Rocks of Washoe, Nevada," U. S. Geol. Surv. Bull. No. 17 (1885).

† 'Memorie descrittive della Carta Geologica d'Italia,' vol. ii.; "Descrizione Geologica dell' Isola d' Elba" di B. Lotti, R. Com. Geol. d' Italia (1886).

‡ Beiträge zur Geologie und Paläontologie der Argentinischen Republic (1885), pp. 198–213.

composition—successive currents being piled upon one another to a great thickness.

(2) Vast deposits of volcanic agglomerate (scoria and dust) are found, sometimes containing many blocks of non-volcanic materials, and thus passing into breccias, which are composed of materials derived from rocks underlying the centres of eruption.

(3) Numerous intrusive masses, frequently nearly horizontal in their disposition (sheets) and sometimes more or less vertical (dykes), are crowded together at these five centres. The largest of these intrusive masses, especially the great nearly horizontal sheets, consist of gabbro and granite, while the smaller ones, the dykes and the peripheral portion of the great bosses and sheets, pass into dolerites, basalts, and "felstones," exactly similar to the materials of the lava-currents.

(4) The basic intrusions tend to form wide-spread sheets, while the acid ones assume those more bulky and lenticular forms for which the name of "laccolites" has since been proposed by Gilbert.

(5) Both the sedimentary and the igneous rocks, among which these masses are intruded, afford very striking illustrations of contact-metamorphism around the intrusions.

(6) Many minor centres of eruption exist in the area, of which the examples of S'Airde Beinn * (Sarsta Beinn) and Beinn Hiant (Beinn Shiant) are described as being among the most striking and typical.

It is interesting to find every one of these conclusions adopted and confirmed in the memoir lately published.

(1) With respect to the centres of eruptive action, it is only necessary to turn to the table of contents of the memoir recently published to perceive that the display of volcanic activity and the development of intrusive masses are alike recognized as occurring at just the five points indicated in 1874. (See the description of these phenomena, T. R. S. E. 1888, pp. 84–100, 122–175, and compare it with Q. J. G. S. 1874, pp. 242–270.) Near one of these great centres, that of Mull, the piled-up lava-streams are asserted, in spite of the great denudation they have suffered, to attain a thickness of over 3000 feet. (See T. R. S. E. 1888, p. 91.)

(2) With respect to the vast masses of volcanic agglomerate at the several centres of eruption, an attempt is made in the recent memoir to minimize their importance. It will be sufficient for my purpose to point out the descriptions given of the tuffs of Antrim (T. R. S. E. 1888, p. 87 *et seq.*), of Mull (*ibid.* p. 83), of Rum

* In 1874 the only maps available for geological purposes were the Admiralty Charts (in which only the parts adjacent to the coast-lines are shown in detail) and some very defective maps issued by private individuals. In all of these a more or less phonetic spelling of the Gaelic names was adopted. In the admirable maps of the Ordnance Survey, which have since been issued, the correct spelling of the Gaelic is given; but many of the names, as now written, have a very unfamiliar appearance to English readers. To avoid confusion, I have placed the old spelling in brackets after the new ones employed on the maps.

(*ibid.* p. 134), and of Skye (*ibid.* pp. 97, 98, 109, &c.). Especially significant is the admission that in Strath we have evidence of whole mountain masses of volcanic agglomerate, and the belief of the author of the memoir that these indicate the existence of a great funnel or vent, originally filled with these materials, *which was no less than two miles in diameter* (*ibid.* p. 108). These accounts may be compared with those which I gave in 1874 (see Q. J. G. S. 1874, pp. 239–242 *et seq.*). Especially close is the agreement between the account given of the volcanic breccias of Rum (compare T. R. S. E. 1888, p. 134, and Q. J. G. S. 1874, p. 253). It is perfectly true, as was pointed out in 1874, and insisted upon in the recent memoir, that at a distance from the great centres of eruption the lava-sheets are usually separated only by thin and unimportant layers of tuff.

(3) The great intrusive masses so often presenting a horizontal disposition and pseudo-stratification, exhibiting evidence of successive extrusion, and the phenomena of segregation or contemporaneous veins, were described in 1874 (see Q. J. G. S. 1874, pp. 238–252, and pl. xxiii. figs. 1, 3, 4, 5). All the details are fully confirmed in the recently published memoir (T. R. S. E. 1888, pp. 111–143 and 151–164).

(4) In 1874 Mr. Gilbert had not described the interesting phenomena to which he proposed to give the name of "laccolites;" but the lenticular form of the great felsitic intrusions was clearly pointed out in my paper (Q. J. G. S. 1874, pp. 268, 269), and the concentric structure of some of the more acid rock masses, so closely resembling the internal character of the domitic Puys in Auvergne, was also indicated (compare Q. J. G. S. 1874, p. 245 (footnote), and T. R. S. E. 1888, p. 162).

(5) The evidences of metamorphism produced in both sedimentary and volcanic rocks by the great intrusive masses, which was pointed out in 1874, is very clearly and fully described in 1888 (compare Q. J. G. S. 1874, pp. 251, 252, &c., and T. R. S. E. 1888, pp. 101–103, 138, 165–167, &c.).

(6) The very full accounts of later eruptions, like that of S'Airde Beinn (Sarsta Beinn) and other smaller outbursts composed of different kinds of acid and basic rock, and seen bursting through the basalt of the great plateaux, as given in the recent memoir, are in full accord with the earlier descriptions (compare Q. J. G. S. 1874, pp. 260–267, and T. R. S. E. 1888, pp. 101–103, 177, 178, &c.).

C. *The Subaerial Origin of the Lavas and Tuffs, and the Tertiary Age of both the Plutonic and the Volcanic Rocks.*

My conclusions on these subjects may be summarized as follows :—

(1) There is a total absence of any contemporaneous marine deposits intercalated among the lavas of the district; but, on the contrary, we find many unmistakable proofs that the lavas and tuffs were ejected under *subaerial* conditions. These proofs consist in the

presence between the successive lava-flows of burnt soils ("laterites" of some authors); of beds of lignite, with the remains of terrestrial vegetation; of sheets of volcanic mud; of river-gravels; and of characteristic lacustrine deposits—including beds of iron-ore analogous to the well-known "lake-ores" of Sweden.

(2) While some of the igneous rock-masses are of strikingly fresh appearance and unaltered character, others exhibit the most unmistakable evidence of having undergone remarkable changes, so that they have come to resemble the igneous products of far older geological periods. There is the clearest evidence, however, that the whole of the igneous rocks, gabbros, and granites, equally with basalts and "felstones," are of *Tertiary* age.

(1) The conclusion as to the subaerial origin of the volcanic rocks of the Western Isles is fully borne out by the detailed memoir just published (see T. R. S. E. 1888, pp. 87–89). This confirmation is particularly important at the present time.

My friend Dr. E. Reyer, in his recently published very valuable 'Theoretische Geologie,' has argued that the highly crystalline character of the gabbro- and granite-masses of the Western Isles of Scotland must be the result of "hydrostatic pressure," and that the weight of overlying and permeable rocks could not possibly account for the production of the granitic texture. He therefore insists that the more highly crystalline portions of the Hebridean eruptions must have been of submarine origin, and contemporaneous with the marine Mesozoic strata among which they lie *.

On the other hand, M. Loewinson-Lessing, adopting a view very generally held in Germany that the ophitic structure—which I have shown to be so characteristically exhibited by the basaltic lavas of Western Scotland—is distinctive of the diabases, has argued that this structure is the result of the outflow of lavas of basic composition under a considerable pressure of sea-water †.

That the ophitic, or "diabasic" structure, as some authors prefer to call it, is found both in Iceland and in Scotland in rocks which were extruded in Tertiary times and under subaerial conditions has been maintained both by M. Bréon and by myself, and I am happy now to be able to fortify my own position by the testimony of the officers of the Geological Survey.

(2) With respect to the Tertiary age of the gabbros and granites, as well as of the basalts and "felstones," the evidence brought forward in the recently published memoir is equally conclusive (T. R. S. E. 1888, pp. 84, 182).

It is impossible, in view of discussions which have taken place upon the subject, to overestimate the importance of the admissions now made.

Dr. Sterry Hunt and others have frequently quoted the case of the so-called "Norites" of the Western Isles as supplying evidence

* Theoretische Geologie von Dr. E. Reyer (Stuttgart, 1888), p. 371.

† Bull. de la Soc. Belge de Géol. &c., tome ii. (1888), pp. 84–87.

that this particular class of rock is characteristic of the Laurentian period.

On the other hand, the accuracy of the conclusions announced by me in 1874 has been again and again disputed, on the ground that the basalt and gabbros had been severally referred to the Jurassic and Laurentian systems.

In the year 1874, Mr. Allport, in his classical paper on the British Carboniferous Dolerites *, showed conclusively that many of the basaltic rocks of Palæozoic age were as fresh and unaltered as many Tertiary lavas. In the paper which I published in the same year, it was pointed out that many of the rocks occurring among the Tertiaries present all the characters which would, if found among older rocks, cause them to be classed as "porphyrites," "melaphyres," "diabases," &c. It is therefore satisfactory to find that the author of the recently published memoir is able to testify that he has "been unable to recognize any essential difference of structure or composition" between the Tertiary igneous rocks and those of far earlier geological age (T. R. S. E. 1888, pp. 74, 145).

IV. Conclusions announced in 1874, which are Disputed in the recent Memoir.

There are several points of detail in which it is asserted that the results obtained by recent studies are at variance with those stated in 1874. In some of these cases I am perfectly willing to confess that I fell into error; but in others I shall certainly be able to show that the mistake has not been on my side. As none of these minor details in any way affects the main questions at issue, I may, for the present, pass them by.

There are two contentions in the recent memoir which do, however, more or less seriously affect the conclusions which my memoir of 1874 aimed at establishing. One of these is a matter of fact and of observation—namely, the relations between the different kinds of igneous rock-masses in the district; the other is a subject of inference and theory—namely, the explanation that is to be given of what I have shown in the preceding pages to be now mutually admitted facts. I will take up these two questions in the order named.

A. *The General Order in which the several Varieties of Igneous Rocks were erupted.*

The memoir of 1874 stated that, as a whole, the more acid rocks of the district were erupted before the more basic ones; but that after the extrusion of the great mass of the basaltic lavas there were numerous sporadic outbursts, and, as the result of these, various acid and intermediate varieties of rock made their way to the surface (see Q. J. G. S. 1874, pp. 272 &c.).

It may be pointed out that this conclusion was not one for which

* Quart. Journ. Geol. Soc. vol. xxx. (1874), pp. 529–566.

I was primarily responsible. As I stated at the time, Professor J. D. Forbes, in 1846, brought forward evidence which he believed showed that the "hypersthene-rocks" (gabbros) are intrusive in, and therefore younger than, the granites *; and Professor Zirkel, in 1871, arrived at the same conclusion †. I certainly found evidence in the central part of Mull and elsewhere which I think is conclusive on the point; and the responsible officers of the Geological Survey of Ireland, two years later, published an account of the relations between the acid and basic rocks in County Antrim which are in striking agreement with these results ‡.

The recently published memoir, however, aims at showing that, both in the Western Isles and in Antrim, the granitic and other acid rocks are younger than the gabbros (T. R. S. E. 1888, pp. 151–171 &c.).

I must here, however, point out an unfortunate misunderstanding into which the author of the recent memoir has fallen with respect to my views concerning the relations of the different volcanic rock-masses.

Though I have insisted that the acid lavas (felstones) were, *as a whole*, ejected before the basic ones (basalts), yet I most clearly and emphatically pointed out that the great masses of granite are intrusive in, and therefore younger than, the great mass of the felstone-lavas. In proof of this I gave a section, seen at the summit of Beinn na Duatharach (Beinn Uaig), in the Island of Mull (Q. J. G. S. 1874, p. 246, fig. 1), which, with its legend, as given in 1874, is exactly reproduced on the next page (p. 198).

I cannot help thinking that much of the difference of view expressed in the recent memoir, as compared with the paper of 1874, is due to the employment of the same terms with a different signification.

At the very outset of my paper I stated that I should employ petrographical names (with certain specified exceptions) exactly as they were defined in Prof. Zirkel's admirable 'Lehrbuch der Petrographie' (Q. J. G. S. 1874, p. 233). I described my "basic, basaltic, or pyroxenic" rocks as in all cases containing olivine (Q. J. G. S. 1874, pp. 233–236 &c.), and I used the old English name of "felstones" as a convenient one for all lavas in which olivine was not an essential constituent. In employing the term "felstone" I desired to make it serve as a field-geologist's name for very varied types of rock, more acid than the olivine-basalts, which I saw would require much time and labour to be expended upon them before exact diagnosis was possible. In the present chaotic condition of petrographic nomenclature, opinions will no doubt differ as to the desirability of limiting the definition of basalt in the manner indicated. Two years later I pointed out the desirability of

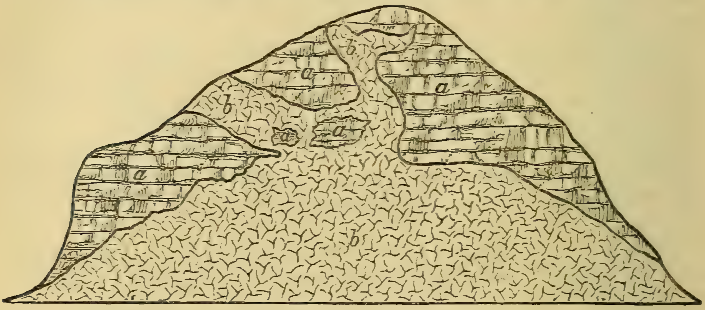
* Edinb. New Phil. Journ. new ser. vol. xl. (1845-6) p. 86.

† Zeitschr. d. d. geol. Gesellsch. Jahrg. 1871, p. 90.

‡ Geol. Surv. Ireland. Memoir on Sheets 21, 28, & 29 (1876), p. 17. Doubt has now been thrown on the accuracy of these maps and memoirs by the author of the recent memoir (T. R. S. E. p. 171, footnote).

removing from the acid rocks the less highly silicated types which had all been included under that head by Bunsen, Durocher, Cotta, and others, and erecting them into a group by themselves *—the "intermediate" rocks. But I think that I cannot fairly be charged with leaving in doubt the sense in which I employed the term basalt in the year 1874; and I have since described these "ophitic

Rocks forming the Summit of Beinn Uaig, Isle of Mull.



a. Felstone-lavas, with agglomerates †.
b. Syenite-granite, graduating into felsite.

olivine-basalts" of the district in considerable detail ‡. I was very careful to point out that many of my "felstones" are as dark-coloured as the basalts, but that they might be distinguished by their macroscopic as well as by their microscopic characters (Q. J. G. S. 1874, p. 236).

Many of the cases cited in the recently published memoir as intrusions of granite and felsite into basalt—and on which so much stress is laid—will, I think, be found to be, as at Beinn Uaig, intrusions into the dark-coloured "felstones" of my first period of eruption §.

I undoubtedly stated that, as a whole, the great ejections of acid material, both as intrusive masses and as lavas or tuffs, took place before that of the gabbros and basalts. But considering how vast a

* Quart. Journ. Geol. Soc. vol. xxxiii. (1876), p. 295.

† These "felstone-lavas" are of very dark grey, almost black colour, and might easily be mistaken for basalts. Microscopically studied, however, they are found to present the very closest analogies with the rock described by M. Bréon from near Stikkisholmur, Iceland (see his Géologie de l'Islande &c. p. 23, pl. iii. fig. 1). This rock, which, like that of Beinn Uaig, contains no olivine, but has a microstructure very similar to that of many andesites, is classed by Bréon as an "augite-andesite." In the second edition of his 'Massigen Gesteine' (1887), p. 687, Professor Rosenbusch adopts this reference of the Stikkisholmur-rock to the augite-andesites, and compares it with rocks of a similar type described by Förstner in Pantellaria. The "syenite-granite" is the usual drusy (miarolitic) granite of the district, which graduates through various granophyric modifications into a distinctly rhyolitic rock.

‡ *Ibid.* vol. xliii. (1886) p. 49.

[§ A reference to the discussion which followed the reading of this paper will show that the author of the memoir of 1888 groups together the andesites and basalts as distinct from the acid rocks. See p. 219.]

period of time must have been covered by these Tertiary volcanic outbursts, and how enormous is the thickness of volcanic materials, it would not be at all surprising to find that some intrusive granites may have been ejected at a later date than some of the earlier-formed basalts and gabbros. I have, moreover, always contended that some ejections of acid materials belonged to a *third* period, later than that of the ejection of either the felstones or the basalts.

There are many observations made by the author of the recently published memoir which, while they are strikingly confirmatory of the view that the acid rocks are, as a general rule, older than the basic ones, appear to me to be quite irreconcilable with the opposite opinion.

Thus it is stated that "there are two horizons on which protrusions of acid materials have been specially abundant. One of these is the base of the bedded basalts of the plateau, the other is at the bottom of the thick sheets of gabbro" (T. R. S. E. 1888, p. 176). Abundant evidence is given in many parts of the memoir of this significant circumstance (*loc. cit.* pp. 116, 117, 172, 173, &c.).

It will, of course, be seen that this fact of the infraposition of the acid to the basic rocks points to the earlier age of the first-named rocks; and the author of the memoir in one case mentions an acid rock which is apparently split up by "a sill of dolerite" (*loc. cit.* p. 173). But in this and all similar cases he rejects the facts which seem to point to the priority of acid to basic rocks, and falls back on the explanation that the acid rocks have a "tendency" to be intruded just in the positions they would occupy if they were older than the basic ones (*loc. cit.* p. 172). I cannot myself accept the view that the acid rocks are in all these cases of an intrusive character.

Again, the author of the recent memoir is compelled to admit that abundant fragments of felsitic materials occur in the agglomerates alternating with the streams of basaltic lava (*loc. cit.* pp. 81, 82, 83, 108, 156, 157, &c.).

Now this fact, which I had myself frequently observed—especially taken in conjunction with the circumstance that many of these "felsitic" fragments present a markedly scoriaceous character—has always seemed to me to be only reconcilable with the preexistence of acid lavas from which these fragments were derived.

This difficulty appears to have been recognized; but it is suggested that the presence of these derived fragments of acid rock among the basaltic ejections is to be accounted for by supposing that the fragments in question were derived from *unejected* masses of igneous material, that were not actually brought to the surface bodily till a much later date! (*loc. cit.* p. 144). The explanation will be regarded by most geologists, I fear, as a "desperate" one.

Lastly, the author of the recent memoir is compelled to admit

that basaltic dykes are found, sometimes in great numbers, traversing both the granites and the felstones. In the central district of Mull it is stated that the vast masses of granite and other acid rocks are penetrated by numerous basalt-veins and dykes; and that these are, indeed, so abundant that the geologist "ceases to take note of their presence" (see T. R. S. E. 1888, pp. 158, 159, and fig. 50).

While, however, I cannot admit that the evidence points to the conclusion that the acid rocks of the Western Isles are of younger age than the more basic ones, there is one point on which I gladly take the opportunity of confessing and correcting an error which my subsequent study of the country convinces me that I fell into in 1874.

It was at that time inferred by me that a considerable interval of time must probably have separated the period of the eruption of the more acid lavas ("felstones") from that of the basalts which flowed from the great central volcanoes. Now, although the evidence is often very clear that the acid rocks had suffered a considerable amount of erosion before they were buried under the outflows of basalt, yet there are so many other indications of great denudation having taken place at different intervals during the whole of the vast periods covered by these Tertiary eruptions, that I am no longer prepared to maintain the special importance of this particular period of quiescence.

On the contrary, the longer I have studied the district the more convincing appears to me to be the evidence of a gradual change from the acid to the basic eruptions. Some of the felstones are augite-andesites and labradorite-andesites, but little more acid in character than the olivine-basalts of the great plateaux; and there are also abundant examples of lavas of more or less acid type having been erupted from the central vents from time to time, while the basalts were being ejected. But, as I have formerly shown, while the extremely liquid basalts flowed to distances of forty or fifty miles from their point of origin, the less fluid, acid lavas seldom flowed to distances of more than ten miles, and are, consequently, found confined to the flanks of the volcanoes from which they issued.

Just as there are examples of "felstone"-lavas among the basalts, so are there cases in which basaltic currents may be found among the older ones of more acid composition,—though it seems to me to be clear that the acid series was, *as a whole*, of earlier date than the basic one. The "pale-coloured felstones of Beinn More," which are claimed by the author of the recent memoir as being posterior to the basalts, are, if my interpretation be correct, a part of the older volcanic ejections.

The great mistake which I made in 1874 was, not in insisting upon the existence of a great series of "felstones" underlying the basalts, but in not recognizing the fact that these felstones include representatives both of the rocks which are more properly desig-

nated as acid, and of those for which I, two years later, proposed the name of "intermediate" rocks *.

I hope shortly to be able to describe some of the chief types of these rocks of intermediate composition—the lavas, including a great variety of andesites, their altered forms (the "propylites"), and their Plutonic representatives (diorites and quartz-diorites). When this is done, it will be seen how numerous and varied are the different types of these rocks which occur in the Western Isles of Scotland, and what striking resemblances they present with masses of the same age in the Faroe Isles and in Iceland. Still more remarkable are the curious modifications which these rocks in Scotland can be shown to have undergone from the action upon them of acid vapours when they were situated in close proximity to the great central vents.

B. *The Existence in the District of great Volcanoes, which have been dissected by Denudation.*

While there is such a close and remarkable agreement between the conclusions enunciated by the author of the recent memoir and those published in 1874, with regard to the phenomena that may be observed in the Western Isles of Scotland; yet, with respect to the *interpretation* of those phenomena and the general theoretical explanation of the mutually admitted facts, there is the widest possible divergence between that author and myself.

The generalization which I arrived at in 1874, and to which especial exception is now taken, may be stated as follows:—

The relations of the different rock-masses around the five centres of eruption in the Western Isles show that these were the sites of five great volcanoes. From their central craters, from parasitical cones on their flanks, and from fissures opened radially around these volcanoes, numerous eruptions, both of the explosive and the effusive type, must have taken place. The data now remaining to us in these old Tertiary volcanoes,—which have been admirably dissected by denudation,—enable us to make an approximate estimate of their dimensions, and to determine the general order of appearance of the materials which were ejected at the surface, and were simultaneously injected into the solid framework of the volcano itself or into the stratified rock-masses subjacent to them.

It is gratifying to find that most of the *observations* upon which I based these generalizations are accepted as correct, and, indeed, are adopted almost without reserve by the author of the memoir.

* The statement that though more acid rocks "occur abundantly in fragments in the volcanic rocks and agglomerate of the plateaux, not a single instance has been observed of their intercalation as contemporaneous sheets among the basalts" (T. R. S. E. 1888, p. 106), is certainly founded on too partial observation. The statement is qualified later on in the account of an andesite lava among the basalts of Eigg, and I shall have to describe many cases of the same kind in Mull, Skye, &c.

It is admitted that very numerous intrusions of both acid and basic rocks took place at just those five centres which were indicated by me in 1874—namely Mull, Ardnamurchan, Rum, Skye, and St. Kilda (T. R. S. E. 1888, pp. 84, 122–170). It is agreed that it is quite impossible to draw any sharp lines of distinction between the materials—whether acid or basic in composition—which constitute these intrusions and the lavas which during the same period were poured out at the surface (*loc. cit.* pp. 76–81, 122, 125, 178, &c.). The existence of enormous masses of volcanic agglomerates and breccias, the result of explosive action near these centres, is granted, although an attempt is made to minimize their importance (*loc. cit.* pp. 83, 87, 108, 109, 134). It is even allowed that there is proof of a crowding of the vents of eruption in the neighbourhood of these five great centres which have been indicated (*loc. cit.* p. 121).

Still more significant are the admissions that there is no evidence of the outflow of basaltic lavas having ceased before the extravasation of the gabbro-bosses, and that it is difficult to suppose that none of the dykes "communicated with the surface and gave rise to outpouring of basalt and the ejection of dust and stones" (*loc. cit.* p. 121). It is granted that "the points of extravasation of the materials," "which ultimately solidified as dolerites, gabbros, troctolites, picrites," &c., "were mainly determined by the positions of the larger or more closely clustered vents of the plateau-period, where lines of weakness consequently existed in the terrestrial crust. Rising as huge bosses through such weak places, the gabbros and associated rocks raised up the overlying bedded basalts, and forced themselves between them, forming thus a fringe of finer-grained intrusive sills and veins around the central amorphous cores of more crystalline material. Whether, in any of these vast domes of upheaval, the summit was disrupted, so as to allow the basic intrusion to flow out as lava at the surface, cannot now be told, owing to the enormous subsequent denudation" (*loc. cit.* p. 183).

It is only necessary to grant the very high probability of this last suggestion being the true one, to bring the views of the author of the recent memoir into complete accord with my own. I have argued that the very complete gradation which is now admitted to exist between the gabbros of the bosses and the ophitic basalts of the plateaux points to the conclusion that—all through the vast periods during which the basalts were being poured out at the surface, from a central crater or from parasitical vents—masses of the same material were finding their way into lower portions of the great cone and among the subjacent rock-masses, and consolidating in a more highly crystalline form. My critic, on the other hand—I fail to see upon what grounds,—asserts that the intrusion of the gabbros took place *after* all, or nearly all, the basalts had been erupted.

Lastly, it is admitted that the central subsidence—to which I particularly called attention as being similar to that which Darwin and other authors had shown to have taken place in the case of many volcanic centres of eruption—really occurred in the case of

the great volcanic centres of the Western Isles of Scotland (*loc. cit.* pp. 94, 142. Compare Q. J. G. S. 1874, pp. 256–7).

So far, indeed, as I have been able to discover, there are three, and only three, reasons adduced by the author of the recent memoir for rejecting the explanation which I offered of the phenomena in 1874; and these we may now proceed to consider.

First. It is said that there is no thickening of the sheets of basaltic lava as we approach the supposed central vents (T. R. S. E. 1888, pp. 99–100).

I may point out, in answer to this, that I have nowhere suggested that the basaltic lava-sheets were thicker nearer their points of origin than further away. On the contrary, I have again and again insisted upon the striking proofs which exist of the extreme liquidity of the basaltic lavas; and such liquidity would militate against the thickening of the lavas as we approach their points of eruption. Very liquid lavas of this type exhibit abnormal thicknesses where they have flowed into hollows (those of Skaptár Jökull are said to have attained a depth of over 600 feet in certain ravines); but I know of no observations which would warrant the conclusion that a progressive diminution in thickness can be detected in such lava-currents as they are traced away from their point of ejection. Further, I have insisted that many of the currents of basaltic lava must have flowed, not from a central crater, but from parasitical cones on the flanks of the great volcanoes, and of such parasitical cones I described a conspicuous example in S'Airde Beinn (Sarsta Beinn). (See Q. J. G. S. 1874, pp. 264–266, and compare T. R. S. E. 1888, pp. 103–104.)

On the other hand, I have always asserted that, as we approach the great centres of eruption, we find the short and bulky andesitic and more acid lava-streams increasing in number till they form a considerable portion of the whole mass (Q. J. G. S. 1874, p. 248). My critic admits the importance of these felstone-lavas in the case of Beinn More in Mull, but with respect to other localities he appears to have overlooked their great number and significance. This seems to arise from the fact that he regards all the masses of acid rocks which lie below the basalts in Mull, Rum, Skye, and Raasay as being intrusive. He makes the important admission, however, that "as we retire from the mountain-tract [that is from the great centre of eruption in Mull] into the undisturbed basalts of the plateau, these acid intercalations gradually disappear." (T. R. S. E. 1888, p. 172.)

In the account which I propose to give of the remarkably varied series of intermediate and acid lavas at the five great centres of eruption, I shall show how they graduate insensibly into dioritic and granitic types on the one hand; while on the other they exhibit, where they approach the great central vents, those curious and interesting modifications of their constituent minerals, from the action upon them of acid vapours, which are so characteristic of the rocks which have been called "propylites."

Secondly. It is asserted that there is an absence of masses of pyroclastic materials (tuffs and dust) such as we should expect to find around great volcanic centres.

In reply to this I may remark that some volcanoes, like those of Hawaii, exhibit very little evidence indeed of explosive activity, and that their cones are almost wholly built up by successively outwelling lava-currents. But, as a matter of fact, there are very abundant evidences of explosive action at these great centres. My critic has completely adopted the account which I gave in 1874 of the agglomerates of Cnoc nam Fitheach in Skye, and of the volcanic breccias in the tract lying south of Allival and Barkeval in Rum. (See T. R. S. E. 1888, pp. 107 & 134, and compare Q. J. G. S. 1874, pp. 253–255.)

When it is admitted that at one of the great centres of eruption, Skye, there are masses of volcanic agglomerate developed on such a scale that it is possible to interpret them as indicating the existence of a volcanic "neck" two miles in diameter; when, at a second centre, Ardnamurchan, one mass of agglomerate (Faskadale), more than a quarter of a mile in diameter, is described, and another (Maclean's Nose) more than half a mile in diameter (T. R. S. E. 1888, p. 106); when, at a third centre, Rum, it is granted that volcanic breccias attain a thickness of 200 feet, extending as a continuous mass for three miles, and in a more interrupted manner much further (*loc. cit.* p. 134); and when, finally, details of similar occurrences are given in the case of a fourth centre, Mull (*loc. cit.* p. 83), it is hard to understand how the deposits of volcanic ejectamenta can be spoken of as being insignificant!

When the geological surveyors come to study the country in detail, they will find how numerous and extensive the beds of tuff and agglomerate really are around the great centres. Of course, such deposits are not so conspicuous as they would be if not covered by taluses of fallen blocks from overlying lavas; and they have, moreover, often suffered greatly from denudation,—*first,* from their greater softness, and *secondly*, from their having in many cases occupied the highest elevations. Enough of them still remain, however, to indicate their character and illustrate their former extent.

Thirdly. It is said that there is no proof of a communication having existed between the great intrusive sheets and dykes of gabbro and dolerite, and the currents of basalt that were poured out at the surface.

Here, too, I must point out that I have never asserted that any such connexion can be *directly* traced. Following Darwin and Jukes, I argued that if the source of an obsidian lava-current could be traced down sufficiently far into the bowels of the earth, every gradation from glass to granite *might be* observed. But in the case of the Western Isles of Scotland, I stated that the proofs of the connexion between the Plutonic rocks and the lavas, necessarily inferential, were as follows:—

The intrusive Plutonic masses, "in their ultimate chemical com-

position, coincide perfectly with the rocks composing the lavas; but in the varieties of their texture and mineralogical constitution they exhibit a much wider range. Thus while we find veins of basalt in which the rock-structure is identical with that of many of the lavas, we find also others in which the rock passes into a glass—tachylyte; while others, again, are composed of the highly crystalline, or granite-gabbro-rocks. Similarly, felstone-veins are related to those of pitchstone and obsidian on the one hand, and to masses of felsite, syenite-granite, and granite on the other." (Q. J. G. S. 1874, p. 238.)

Not only did I refrain from asserting that an intrusive mass of gabbro and dolerite could be traced passing into the basaltic lava-current, of which it formed the filled-up duct leading to the surface, but in my diagrammatic sections drawn to illustrate what I supposed to be the real interpretation of the phenomena, I represented the supposed connexion between the great, nearly horizontal sheets of intrusive gabbro and dolerite and the superficial lavas by *dotted lines* (see Q. J. G. S. 1874, pl. xxiii. fig. 3).

The fact is, I perceived then, as I do now, that only by the most extraordinary series of accidents could we expect a mass which has consolidated at such a depth as to form a gabbro, to have its connexion with the lava-current that reached the surface preserved in such a way as to permit of the change being followed step by step.

How fully my critic has adopted, and how clearly he has expressed the views which I put forth concerning the actual transitions from gabbro into dolerite, from dolerite into basalt, and from basalt into tachylyte, I have already pointed out. He states quite truly that in the gabbro-bosses "there are evidences of successive discharges or extravasations of crystalline materials, during a probably protracted period of time, and in the intricate network of veins crossing each other, and the general body of the rock in every direction," . . . . . (the geologist) "will recognize the repeated renewals of subterranean energy." (T. R. S. E., 1888, p. 130.)

It will thus be seen that we both believe that the basalts of the plateaux and the gabbro-masses around the five great centres were alike formed by a number of successive manifestations of the volcanic forces extending over enormous periods of time. We are at one in the opinion that in chemical composition, and in mineralogical constitution, the gabbros and the basalts show the most striking analogies; while, in texture, the holocrystalline rocks exhibit remarkable transitions into the hypocrystalline ones. But while I have argued that the same series of volcanic throes which brought the basalts to the surface, may have produced *at the same time* the vertical and horizontal fissures, and injected them with the materials of the gabbro, my critic asserts that the gabbro-injections *belong to a distinct and later period* than the outflow of the basalts.

It is scarcely necessary to remark that the explanation I have given is by no means inconsistent with the view that many of the

younger of the gabbro-bosses may be of later date than the oldest of the basalt-flows—those, namely, which have escaped denudation. We are equally agreed as to the enormous periods occupied by the eruption of the basaltic lavas, and as to the vast amount of denudation which they have since suffered.

V. The Alternative Theory of "Fissure-Eruptions."

We have now, I think, dealt with the arguments which Dr. Geikie brings forward as tending to throw doubt on the theory of the origin of the volcanic rocks of the Western Isles of Scotland, which was proposed by me in 1874. So far as I can understand them, the observations made by the Director-General and the officers of the Geological Survey—especially as to the order of appearance of the several varieties of igneous rock in the area in question, and in the closely related districts of Antrim and Carlingford—are quite capable of being completely reconciled with the views I have propounded. But Dr. Geikie has, in 1880, proposed a rival theory *; and to this theory, in support of which a number of arguments are now adduced, we must proceed to direct attention.

A. *Can great Basaltic Plateaux be formed by ordinary Volcanic Action?*

It may be well at the outset to consider an *à priori* objection which has been frequently raised,—in which doubt is thrown upon the possibility of thick plateaux of basaltic lava, covering many thousands of square miles, having been poured out from ordinary volcanic vents.

Now, in seeking to explain the volcanic phenomena of the Hebrides and the north of Ireland, no illustrations drawn from modern examples of eruptive activity are likely to be of greater value and appropriateness than those derived from the area which comprises the Faroe Isles and Iceland, and which stretches away northward into Greenland. As I have already shown, those districts form parts of a great petrographical province, and the various types of lava poured out at successive periods are wonderfully similar throughout the whole of the vast area. For some reason, not yet explained, however, the eruptive activity, which at the central part of the area (Iceland) is still in full vigour, appears to have died out, probably in the Pliocene period, both in the northern part of the province (Greenland) and at its southern extremity (the British Isles).

I know of no valid grounds whatever for doubting that the great plateaux of basaltic lava which cover so large an area in Iceland have been poured out by a long succession of outflows from ordinary volcanic vents. Within the comparatively short period covered by Icelandic history, we have the example of the eruption of 1783 at Varmárdalr (usually spoken of as the Skaptár Jökull eruption). From the carefully prepared accounts of this eruption, drawn up by

* 'Nature,' vol. xxiii. p. 3 (November 4, 1880).

a Danish Commission appointed for the purpose, and which have been confirmed by the observations of many travellers who have since visited the district, we learn that two streams of very liquid basaltic lava having lengths of from 40 to 50 miles, with breadths varying from 7 to 15 miles, and an average depth of 100 feet, were poured out during this eruption. Professor Bischoff has made a very remarkable estimate, which shows that the quantity of material brought from within the earth's crust and spread over the surface in this single outburst exceeds the bulk of Mont Blanc *.

It is scarcely necessary to point out that a succession of flows of such magnitude as that of Skaptár Jökull, continued through the long periods of time covered by the Tertiary epoch, would be amply sufficient to produce the great basaltic plateaux of Iceland, without calling in the aid of any sudden and overwhelming extravasation of lava, to which we can find nothing approaching a parallel among the volcanic phenomena of the present time.

It is only fair to Dr. Geikie to point out that his own observations, and those of other members of the Geological Survey, are clearly shown to support the conclusion that the plateaux of basalt in Antrim and the Western Isles are built up of a great number of separate lava-streams, some of a volume comparable to the lava-sheets of "Skaptár Jökull," others of much smaller bulk, with not a few of quite insignificant dimensions.

After pointing out that the thickness of the individual lava-sheets in Antrim and the Scottish Isles varies from 60 or 70 feet to only 6 or 8 feet, Dr. Geikie goes on to say:—

"Each bed appears, on a cursory inspection, to retain its average thickness, and to be continuous for a long distance. But I believe that this persistence is in a great measure deceptive. It is not often that we can follow the same bed with absolutely unbroken continuity for more than a mile or two. Even in the most favourable conditions, such as are afforded by a bare sea-cliff on which every bed can be seen, there occur small faults, gullies where the rocks are for the time concealed, slopes of débris, and other failures of continuity; while the rocks are generally so like each other that on the further side of any such interruption it is not always possible to make sure that we are still tracing the same bed of basalt which we may have been previously following. On the other hand, a careful examination of one of these great natural sections will usually supply us with proofs that, while the bedded character may continue well marked, the individual beds die out, and are replaced by others of similar character. On the south coast of Mull, for instance, cases may be observed where the basalt of one sheet abruptly wedges out

* If it should be asserted, as has sometimes been done, that the Icelandic eruptions are themselves not ordinary volcanic outbursts, but "fissure-eruptions," it is only necessary to refer to the accounts given of the "Skaptár Jökull" outbreak by the Danish Commission and subsequent authors. The explosive action was so violent as to produce phenomena quite comparable to those occurring at Krakatoa in 1883, and lines of cinder-cones were thrown up, just as in the eruptions which take place on the flanks of Etna,

and is replaced by that of another. Where both are of the same variety of rock, it requires close inspection to make out the difference between them; but where one is a green, dull, earthy, amorphous amygdaloid, and the other is a compact, black, prismatic basalt, the contrast between the two beds can be recognized from a distance. Again, along the west coast of Skye, the really lenticular character of the beds can be well seen." (T. R. S. E. 1888, pp. 80, 81.)

The author goes on to show that the detailed study of the lavas of Antrim, where the Geological Survey has been completed, strongly supports the same views.

In reply to those who believe that such basaltic plateaux as those of Antrim, consisting of successive lava-sheets, lying almost horizontally, and piled upon one another to a very great thickness, could not possibly have been poured out from volcanoes, I cannot do better than point to the example of the Sandwich Islands. And very opportunely we have just at the present time new and important light thrown upon that interesting district by the valuable studies of Captain Dutton *, and the still more striking observations recently made by the veteran Professor J. D. Dana †. Geologists all over the world may well hesitate as to which calls for the greater admiration—the vigour and enthusiasm which prompted our esteemed Foreign Member to undertake a journey of ten thousand miles in order to clear up difficulties left in his original studies of the district in 1840—or the new and valuable results obtained by the investigations of one who, after nearly half a century of thought and inquiry, has returned to the field of his early observations.

The island of Hawaii, taking only that portion of the mass which is at present above the sea-level, has an area almost identical with that of the basaltic plateau of Antrim, and the rocks composing the island, *though undenuded*, form a great mass, the slopes of which seldom, if ever, exceed a few degrees. The individual lava-streams, like those of Antrim, are of the most varied bulk and, like them, also lie almost horizontally: in many parts only insignificant beds of tuff or ash can be detected between the different lava-sheets. Yet there cannot be the smallest doubt that this plateau of basalt has been formed by ejection from the three great volcanoes—Mauna Loa, Mauna Kea, and Hualalai. Either from the summit-craters of those volcanoes or from the numerous parasitical vents that have been opened upon their flanks have the successive lava-currents,—sometimes small and insignificant, at other times forming vast floods of molten rock—been poured out.

The examination of the Antrim-plateau, which has been carried on during the last twenty-five years by different officers of the Geological Survey, has shown that too much importance must not be attached to the, at present, almost horizontal position of the several lava-sheets of which it is composed, or to the inclinations which they can now be shown to exhibit. The author of the recent memoir states that "the varying dip of the beds must be attributed

* Fourth Rep. U. S. Geol. Surv. pp. 81–219.
† Ann. Journ. Sci. 3rd ser. vols. xxxiii.–xxxvii.

mainly to post-volcanic movements, or at least to movements which, if not later than all the phases of volcanic action, must have succeeded the outpouring of the plateau-basalts" (*loc. cit.* p. 89). I have again and again insisted upon the same fact in the case of the basaltic plateaux of the Western Isles of Scotland, and have especially dwelt upon the dip of the lava-sheets towards the central vents (Q. J. G. S. 1874, pp. 256–258.), and the correctness of these observations the author of the recent memoir appears not only to fully admit, but also to adopt, for he says:—"There appears also to have been a general tendency to sagging subsequent to the gabbro protrusions, and the inward dip thereby produced has probably been instrumental in effacing at least the more gentle outward inclinations caused by the uprise of the eruptive rock." (T. R. S. E. 1888, p. 142.)

B. *The Age of the Basic Dykes of North Britain.*

The author of the recent memoir, in seeking to give an explanation of the volcanic phenomena of the Western Isles of Scotland, begins by laying much stress on the great importance of the numerous dykes which traverse the central and southern districts of Scotland and the North of England. For the sweeping generalization which he announces, however, that those dykes or, at all events, the great majority of them, were formed during the Tertiary period, I confess I can find no evidence. That the great mass of the basaltic dykes in the Western Isles of Scotland, and in Antrim, many of which can be shown to radiate from the great centres of eruption, are of this age, I fully admit; but when the numerous dykes of the Central Valley of Scotland, of Fifeshire, of Forfarshire, the Southern Highlands, the Borderland, and the northern counties of England are all claimed as fissures from which ejections took place in Tertiary times, it would have been satisfactory to have had the grounds of such a very startling conclusion a little more clearly stated. Such field-evidence as is available only suffices to prove that while some are later than Silurian or Ordovician strata, others are younger than Old-Red-Sandstone or Carboniferous times.

Two sets of facts on the other hand make me think this sweeping generalization a very doubtful one indeed. Mr. Allport's valuable researches concerning the Carboniferous Dolerites showed how remarkably fresh are some of the basic rocks of this age; and his studies also demonstrated the fact that the materials filling many of the dykes are perfectly similar to some of the lavas which were undoubtedly erupted during the Carboniferous period in the South of Scotland. The author of the memoir we are now considering, it is true, at one time maintained that at Arthur's Seat (where some of the doleritic lavas of freshest appearance are found) there was evidence of eruption having occurred in the Tertiary period; but this conclusion he has long since abandoned. I see no ground myself for doubting that many, and perhaps the great majority, of the basaltic dykes of the Southern Highlands, of the Central Valley of Scotland, of the Border-

land, and in the North and West of England are really of Newer Palæozoic age, and are connected with the ejection of the very similar lavas that were erupted during that period.

That a few dykes in the North of England which intersect the Mesozoic strata are probably of Tertiary age, has long been very generally admitted; but, as Mr. Teall has so well shown, the Tertiary dykes consist of very characteristic materials (augite-andesites or "tholeites" of Rosenbusch), while other truly basaltic dykes in the same district appear certainly to be of far older date.

That certain dykes, like that of Eskdalemuir, which cannot be proved to intersect strata younger than Palæozoic, are probably also of Tertiary age, is highly probable, from the similarity of their materials to those of the Cleveland and other late dykes; but in the large and valuable series of facts brought forward by the author of the recent memoir—in which he summarizes the results of the labours of the Geological Survey in the North of England, in Western Scotland, and in Ireland—I fail to find any evidence based either on the petrographical character of the dykes, the directions in which they run, or any other peculiarities, that we can safely discriminate between the Newer Palæozoic dykes and those which are of Tertiary age. Still less can I find any evidence for the confident assertion that the great majority of the basic dykes over such a wide area must all be of Tertiary age.

It is an interesting fact, to which I called attention in my original memoir, and the full evidence for which I hope shortly to lay before this Society, that the materials ejected during the latest eruptions in the West of Scotland are augite-andesites ("tholeites" of Rosenbusch), presenting the most striking similarity to the rocks of the undoubtedly later dykes in the North of England, described by Mr. Teall *. It is on this ground that I continue to maintain that these dykes represent the long radiating fissures which were produced after the great central vent became extinct, and that in many cases they give rise to lines of cinder-cones with issuing lava-streams, similar to the well-known "puys" of the Auvergne (Q. J. G. S. 1874, pp. 260–267).

C. *Insufficiency of these Dyke-fissures as Sources of the Plateau-basalts.*

Even if we were to grant the contention that a large proportion of the North British basic dykes are really of Tertiary age, I believe that the fissures occupied by those dykes are quite inadequate to have served as the vents from which such enormous masses as the basaltic lavas of the plateaux could have been outpoured.

I am happy to find that the author of the recent memoir is quite at one with myself in regarding the existing patches of these basaltic lavas as mere vestiges, which have escaped denudation, of masses originally having a far greater thickness and covering a much wider

* Quart. Journ. Geol. Soc. vol. xl. (1884), p. 209.

area. Where only a few scattered islets now remain, we both believe that extended and thick plateaux of basalt must have once spread over the whole intervening area. I have maintained that, away from the great central vents of the district, these basaltic lavas formed masses which were, in places, 2000 feet in thickness, but that, around the vents, they attained to a far greater depth. My critic thinks that even where there were no great vents, the plateaux were as much as 3000 feet in thickness! (T. R. S. E. 1888, pp. 91, 99; compare Q. J. G. S. 1874, pp. 244, 255, &c).

Now even if we accept a large proportion of the basic dykes as being of Tertiary age, we must take into consideration several very important facts.

First.—Many of these dykes, for large portions of their course, do not, even at the present day, reach the surface at all. This fact was long ago pointed out by Winch, and has been confirmed by the observations of the Geological Surveyors and of Mr. Teall. The recent admirable studies carried on by Mr. G. Barrow in the North of Yorkshire have demonstrated the frequency of this upward dying-out of the Cleveland-dyke over considerable distances *. But the present surface of the country must be many hundreds or thousands of feet below that which existed in early Tertiary times; and if we could restore the vast masses of rock removed by denudation, the abrupt upward termination of the dykes would doubtless be found to be of much more frequent occurrence; and it is of course only where the dykes actually reached the old surface early in the Tertiary period that they could have served as lava-conduits.

Secondly.—While a few of these dykes are 50 feet or even more in breadth, the great majority of them are of far smaller dimensions, many of them, indeed, being quite insignificant; and it has always appeared to me difficult to believe that such enormous floods of lava could have been erupted through channels so narrow.

Thirdly.—If it be argued that even comparatively narrow fissures might have given rise to enormous outflows of lava, provided they were of the nature of habitual vents, then a fresh difficulty has to be faced. In such cases we might surely expect that the long-continued flow of molten materials through the same channel would have given rise to the most striking and profound contact-metamorphism on the sides of the fissure. But this is what we never find to be the case; as the author of the recent memoir justly remarks, "evidence of any serious amount of alteration is singularly scarce, a slight induration of the rocks on either side of a dyke is generally all that can be detected" (*loc. cit.* pp. 62, 63).

It was on these and similar grounds that I long ago rejected the suggestion so very frequently advanced by some of the older geologists, and which has been revived at various times by my critic, that the plateau-basalts or "trap-rocks" are masses of igneous material which have come up through the dyke-fissures and overflowed the surface. In the case of the Western Isles of Scotland, at all events,

* The Geology of North Cleveland (1888), pp. 60–64.

I have shown that it is not necessary to resort to such a theory of the origin of "trap-rocks."

D. *Arguments drawn from the Lava-fields of the Western Territories of the United States.*

In the year 1876 the author of the memoir which we are now considering published a Geological Map of Scotland, in which he, for the first time, publicly renounced the view that the gabbros of the Western Isles are of metamorphic origin and of Laurentian age. The relations of the igneous rocks to one another, as indicated upon this map, were precisely those which I had announced two years before.

But in 1879 the same author, as he himself informs us, undertook an excursion to the Yellowstone Park, and, while on his journey to that famous locality, observed facts which profoundly modified his views concerning the mode of origin of the igneous rocks of his own country. Riding across the plains of the Snake River, he was struck by the absence of volcanic cones in a wide area covered by basaltic lavas; and he came to the conclusion that the lavas must have reached the surface by means of fissures opened in the subjacent rocks.

Now I cannot help remarking, at the outset, that this generalization, in the case of the lavas of the Snake-River district, appears to have been a somewhat hasty one. The opportunities for careful observation during a rapid ride of this kind must have been necessarily few; and, as Darwin pointed out long ago, the most careful observer is very prone to ascribe to a single outflow of lava the materials which were actually accumulated by a number of distinct ejections. As Darwin well showed, in his 'Volcanic Islands,' it is often impossible to detect the limits of the different, comparatively fresh flows, except by studying the age of the vegetation which has sprung up on each of them.

The statement that the basalts of the Snake River welled out in floods from fissures in the subjacent rocks, is admitted to be purely conjectural; and several of the observations which the author of the statement has made with regard to the district appear to me to be quite irreconcilable with his theory. He admits that cinder-cones were seen here and there during his rapid ride; and when we remember how liable such cinder-cones are to be swept away, firstly by the outwelling of lava from their craters, and secondly by the ordinary agents of subaerial denudation, this fact is a sufficiently significant one. That a considerable amount of denudation has taken place in the Snake-River district is shown by the circumstance that it presents, according to the author's own description, "low hummocks or ridges of bare black basalt, the surfaces of which exhibited a reticulated pavement of the ends of columns" *. These appearances, which are illustrated by a drawing, are scarcely consistent with quite fresh lava-streams, but are exactly what is met

* See Text-Book of Geology (1882), p. 257.

with when the scoriaceous surfaces and upper layers of streams of lava have been removed by denudation. But if denudation has done so much work on the solid lava-currents, what may we not expect it to have effected in the case of cones composed of loose scoriæ?

But other observers who have visited the district, and had far greater time and opportunity for studying the phenomena, have come to very different conclusions from those which my critic announces.

Captain Raynolds, one of the earliest explorers of the Snake-River district, examined the country in 1868, and was accompanied by Dr. Hayden, who described volcanic agglomerates as by no means wanting in it *.

Dr. Hayden, visiting the district again in 1872, found sections that proved the basalts not to be massive floods of lava, but thin cappings overlying beds of trachytic tuff and other rocks, and he describes cones, one of them 500 feet in height, from which these lavas seemed to have issued. His descriptions forcibly remind us of some portions of the Auvergne †.

At a subsequent date Mr. Clarence King described the basalts of the Snake River as being well exposed in the Snake Cañon, where he found them to consist of thin flows of basalt, superposed one upon the other; and the evidence found in the Cañon is said to distinctly negative the idea that the lava could have flowed from a plexus of dykes, inasmuch as such dykes are few in number, and sometimes none of them are found for very great distances ‡.

But in his recent memoir the advocate of "fissure-eruptions" has sought to extend the generalization at which he arrived from an inspection of the Snake-River basalts to other areas of the Western States of America; and first among these fresh examples he places the basalts of the Uinkaret Plateau described by Captain Dutton in his admirable work 'The Tertiary History of the Grand Cañon District.'

Captain Dutton's clear descriptions and Mr. W. H. Holmes's beautiful drawings of the scenery of the district give to every geologist the opportunity of judging for himself how far the hypothesis of fissure-eruptions is supported by the district referred to. We are told that from one point of view alone the observer may see "120 to 730 distinct cinder-cones, and that there are many others that will escape detection." Many of these are said to be quite small, but others are from 700 to 800 feet in height and are a mile in diameter §.

The maps ‖ of the district and the beautiful drawings of Mr. Holmes fully confirm this description. The panorama seen from Mount Trumbull, where we observe stratiform rocks capped by basalts and cut through by streams with later currents of lava issuing from cinder-

* See Captain Raynolds's Report, published in 1868 and 1869, chapter x. pp. 85, &c.; quoted in U. S. Geol. Surv. of Territories, 1872.

† *Ibid.* for 1877.

‡ U. S. Geol. Explor. of Fortieth Parallel, vol. i.; Systematic Geology pp. 672–3.

§ Tertiary History of the Grand Cañon District (1882), pp. 104–112.

‖ Atlas to accompany the above; see plates vii., viii., ix. and x.

cones, so exactly reproduces the features illustrated by Mr. Scrope in his well-known panoramic views of the Auvergne, that it seems difficult to understand how any geologist could maintain totally distinct modes of origin for these features in the two cases.

Captain Dutton's remarks on the High Plateaux of Utah and the lava-fields of New Mexico are also quoted as giving still further support to the theory of "fissure-eruptions."

A reference to these writings of Captain Dutton, however, shows that cones and craters are by no means absent in the districts referred to; they are, indeed, said to be very numerous in some parts of the areas, though usually of small size. Moreover the lava-fields are stated in some cases to have suffered so greatly from denudation that it would be a hopeless task to look for cinder-cones upon them.

But there is one very important circumstance which seems to have been unfortunately overlooked by my critic. Captain Dutton, after studying the lava-fields of the Western Territories, and showing some disposition to refer them to "fissure eruptions," paid a visit to the Sandwich Islands, and there—amid the abundant proofs afforded to him of the fact that from the summit and sides of true volcanoes highly liquid basaltic lavas are often poured out, with but a very slight accompaniment of explosive action—he very candidly confessed that he felt he might have been in error in invoking the aid of the "fissure-eruption" hypothesis to account for the phenomena witnessed by him in his own country. Captain Dutton's remarks are so much to the point that I cannot do better than quote them.

Referring to the lava poured out from Mauna Loa in 1855, Captain Dutton remarks:—

"As I looked over this expanse of lava, I was forcibly reminded of some of the great volcanic fields of the western portion of the United States, where the eruptions are of such colossal proportions that they have received the name of massive eruptions. Richthofen, after studying many of these lava-fields in California and Nevada, was led to the conclusion that they had burst forth from great fissures, inundating large areas of country with fiery seas of basalt. He was led to contrast the immense volume of these rocks with the comparatively insignificant streams which have emanated from Vesuvius, Ætna and other modern volcanoes, and concluded that the incomparably grander overflows of Western America must have occurred under circumstances differing widely from those of ordinary volcanic eruptions. Although the volcanic rocks of Western America may be considered as very well exposed, as compared with rocks of equal antiquity in other portions of the world, they would be regarded as relatively obscure by any one who has had an opportunity to inspect carefully the recent lavas of Mauna Loa. I am by no means certain that Richthofen's conclusions are wrong. But here is a lava-flow, the dimensions of which fully rival some of the grand pliocene outbreaks of the west, which demonstrably differs in no material respect, excepting in grandeur, from the much smaller eruptions of normal volcanoes"*.

* Fourth Rep. U. S. Geol. Surv. p. 156.

In several other passages of the same Report Captain Dutton clearly intimates that his belief in "fissure-eruptions" was most seriously shaken by what he saw in the Sandwich Islands.

VI. Conclusion.

But even if it were conclusively demonstrated that the basalts of the Snake-River area, of the Uinkaret plateau, of the Highlands of Utah, and of the plains of New Mexico, could only have originated in "fissure-eruptions," I fail to see how this affects the question of the existence of great volcanoes in the Western Isles of Scotland. It would seem that districts which have only been hastily traversed are scarcely likely to afford evidence that can be placed in comparison with the clear and unmistakable indications found in a district which has been made the scene of careful and searching investigation.

It is very difficult to understand what idea the advocates of "fissure-eruptions" wish to convey by their favourite phrase. If by using it they intend to imply that volcanic action takes place along lines of fissure, I know of no vulcanologist who has ever denied it. In that sense *all* volcanic outbursts are "fissure-eruptions." If it be meant to indicate that the outflow of lava from a vent may take place with little or no explosive action, this is equally a part of the creed of all vulcanologists.

But if, on the other hand, it be intended to assert that, either during the Tertiary or any earlier geological period, there is evidence that lavas were extruded upon the earth's surface under wholly different conditions from those which prevail in the volcanic areas of the present day, this is a proposition which I utterly deny:—and I challenge the supporters of "fissure-eruptions" to bring forward a particle of evidence in its support *.

The study of the Hawaian volcanoes has long ago shown how remarkably the effusive action, resulting in the outwelling of successive sheets of lava, may preponderate over explosive action at certain volcanic vents.

Captain Dutton very justly remarks that "the long and gentle slopes of Mauna Loa are merely the surface of a mass of lavas which have been piled over each other in the form of lava-streams, poured out at intervals throughout an epoch of vast but unknown duration. These great lava-floods burst out seemingly in a most capricious manner, here there and everywhere. They break out far more frequently at or near the summit than upon the lower flanks of the mountain, and so vast is the amount of lava outpoured at each eruption, that the streams often reach literally from the summit to

[* My difficulty in understanding what is meant by a "fissure-eruption" has been only increased by the explanations offered after the reading of the present memoir (see page 219). It is said that the lavas have not flowed out "directly from long open fissures, but that vents were established on such fissures, sometimes of considerable size, with the usual accompaniment of volcanic eruptions." I presume, then, that when an outburst occurs at the summit-crater of Etna, it must be called a *volcanic* eruption, but when it takes place on the flanks of the mountain, like that of 1874, so well described by Silvestri, it is a *fissure*-eruption !]

the sea" [that is distances of from 30 to 40 miles!], "spreading out from a quarter of a mile to two or three miles in width. Upon such a broad surface as that of Mauna Loa it must necessarily happen that some portions may lie for centuries unscathed by fire, and during this period of immunity the lavas decay, soil is formed upon them and accumulates to the depth of many feet"*.

The facts which I observed in the Western Isles of Scotland led me, in 1874, to state in very similar terms the real nature of the basaltic plateaux of that district. I wrote as follows:—

"The whole of these facts point to the conclusion that, during the period of the emission of the great lava-floods which form the enormous plateaux of the Hebrides and Antrim, the surfaces over which they flowed were above the sea-level, and, further, that intervals of sufficient duration occurred between the outpourings of the lava-streams to admit of the formation of those very interesting intercalated deposits, which are in every case of a terrestrial, fluviatile, or lacustrine origin"†.

The study of the Hawaian volcanoes by Captain Dutton, and especially by Professor Dana, has thrown much new light upon certain phases of volcanic activity; but the formation of great plateaux built up by successive outpourings of lava of basaltic composition and of great liquidity had been long before fully recognized by Mr. Scrope and other vulcanologists.

I have no wish to suggest that the great volcanoes of the Western Isles of Scotland were of the same type as those of the Sandwich Islands. On the contrary, I believe that there is ample evidence to show that, while the great basaltic plateaux which surround those volcanoes were built up by successive outflows of very liquid lava from their summits and flanks, yet a considerable amount of explosive action, indicated by many relics of great masses of tuffs, took place both at the central craters and from the parasitical vents.

The eruption of the basaltic lavas was preceded, and to some extent accompanied by the extrusion of lavas of more acid composition—andesites, dacites, and rhyolites; but these lavas, as I showed, were generally wanting in the great liquidity which characterized the basaltic extrusions, and so are, for the most part, found confined to the immediate vicinity of the great eruptive centres.

During fifteen years I have devoted my attention to the study of the varied products of these great volcanoes of the Western Isles of Scotland, and I have again and again revisited them to clear up difficulties as they arose in the course of those studies. Many errors in points of detail I am prepared to admit, but of the truth of the main propositions enunciated in my memoir I have become more and more convinced, the longer I have studied the subject.

If such large quantities of volcanic material, both of acid and basic composition, were transferred from the interior of the earth's crust to the surface, then surely we ought to find, in a greatly denuded area, the traces of those conduits and channels by which the igneous

* Fourth Report U. S. Geol. Survey, p. 93.

† Quart. Journ. Geol. Soc. vol. xxx. (1874), p. 230.

materials found their way from below. The materials filling these conduits, I argued, would have consolidated slowly and under great pressure, and I therefore inferred that while agreeing in ultimate chemical composition with the lavas, they would exhibit a more highly crystalline structure. I then showed that in the great bosses, sheets, and dykes composed of gabbro and granite we have just such masses of rock—occupying precisely the positions they might be expected to do, if the interpretation which I gave of the structure of the country was the true one. On the other hand, I maintain that the long narrow dykes are altogether inadequate as the sole channels for the extrusion of these enormous volumes of lava.

The hypothesis of "fissure-eruption" appears to me now, as it has always done *, as unnecessary as it is vague. Effusive action, the welling-out of great masses of lava, is as much a characteristic of volcanoes as is the dispersal of scoriæ, lapilli, and dust by explosive action. In the Sandwich Islands we have an admirable example of the formation of plateaux built up of basaltic lava-streams, with only small and rare intercalations of volcanic tuffs. In the great tuff-cones of Java and their remarkably explosive outbursts we have the other extreme type of volcanic activity admirably exemplified. The study of the recent tremendous catastrophe at Krakatoa was particularly interesting, as affording to us a striking instance of the explosive type of volcanic activity, so strongly contrasted with the effusive type, as illustrated in the Sandwich Isles. But I am quite at a loss to understand why the explosive action that has produced the great tuff-cones of Java should be regarded as "*ordinary* volcanic activity," while the effusive action which has given rise to the basaltic plateaux of the Sandwich Islands should be denied that title.

Professor Dana, after very clearly and forcibly pointing out the distinction between the two types of volcanic activity, very justly adds :—"The marked contrast between volcanoes of the Mount Loa and Vesuvius types, based on the liquidity of the lava, making Mt. Loa discharges to be almost solely outflows, and those of Vesuvius both upthrows of cinders and outflows of lava, has been sufficiently explained. With this exception, the contrast as to their eruptions as well as to their ordinary action is far less than is generally supposed. There is no reason to regard the forces as different in kind or mode of action "†.

The volcanic outbursts of Iceland in recent times—and there is every reason for believing that those of the British Islands during the Tertiary periods were precisely similar to them—combine in a most striking and instructive manner the explosive and the effusive types of activity. The eruption of Varmadalr (Skaptár Jökull) in 1783 was not more remarkable for the enormous volume and great liquidity of the lavas, than for the violently explosive action which accompanied their extrusion—these explosions producing effects quite comparable to those which resulted from the Krakatoa outburst, just a century later ; the Icelandic eruption moreover resulted in the

* Volcanoes, what they are and what they teach (1881), p. 188.
† Amer. Journ. Sci. ser. 3, vol. xxxvi. pp. 172, 173.

formation of lines of scoria-cones similar to those so constantly formed when an eruption takes place on the flanks of Etna.

It is very necessary that the true nature of the phenomena displayed at Krakatoa and at Mauna Loa respectively should be correctly appreciated, and that the manner in which, at all volcanic centres, the two kinds of activity—of which these are the extreme types—may be found in ever varying combinations should be clearly understood. When this result is arrived at, I am convinced that the hypothesis of "fissure-eruptions" will soon sink into that same oblivion which has already overtaken its predecessor and parent "the theory of the trap-rocks."

Discussion.

Dr. Geikie, alluding to the fact that his memoir, which had been reviewed by Professor Judd, had probably not yet been seen by many of those present, who were therefore unacquainted with the mass of detailed observations on which his conclusions were based, proceeded to give a history of his researches in the volcanic rocks of the West of Scotland. He had first broken ground among them more than 30 years before, and after publishing various papers on the subject, had presented to the Society in 1871 what he intended to be the first of a series of papers on the Tertiary volcanic rocks of the British Isles. Before the second paper of the series was ready, Professor Judd entered the field, and by his paper of 1874 covered most of the ground that he himself had been working over. He laid aside the subject for a few years, but an excursion into Western America in 1879 gave him new insight into the volcanic history of Western Scotland, and he then resumed his researches, and continued them until he was able to publish, last May, the large memoir which had been criticized by Professor Judd *. He had not been able to confirm his critic's conclusion as to the order of succession among the volcanic rocks, which he found to have been the reverse of what had been stated. But with a strong dislike of controversy, he had refrained from emphasizing the differences of opinion between Professor Judd and himself, and after stating generally his disagreement, had abstained from pointing out what he believed to be serious errors of observation, and preferred to quote from the paper of 1874 when he agreed with it. He wished emphatically to declare that his Memoir was not official work of the Geological Survey, but that for any demerits it might contain he was himself solely responsible. Exhibiting on the wall an enlarged copy of Professor Judd's map of Mull, he showed also a rough enlargement of his own map of the same island, which, out of deference to Professor Judd, whose work it contradicted, he had refrained from publishing in his paper, but which he now felt compelled to produce. He pointed out what he considered to be the grave errors in the former map.

There was in reality no central core of granite with a ring of

* Trans. Roy. Soc. Edinb. vol. xxxv. pp. 21–184.

felstone and masses of acid breccias and tuffs, as laid down by Prof. Judd. The acid rocks were confined to a few bosses and hundreds of dykes and veins, and instead of forming the oldest masses of the volcanic series, as, trusting to the map of 1874, he had believed to be the case, they were actually the youngest, and could be seen in innumerable localities, sending veins into them. He had been unable to discover any trace of felstones which had reached the surface before the outflow of the basalts. The latter he had everywhere, through Mull, Rum, Eigg, and Skye, found to be the oldest lavas. Next in age came the gabbros which had been injected into the already solidified basalts, andesites, &c. of the plateaux; and lastly the granophyres and other acid rocks were erupted through the whole, except the youngest basic dykes.

With regard to the criticism which had been offered as to "fissure-eruptions," he thought that some misapprehension existed. He did not suppose that the lavas flowed out directly from long open fissures, but that vents were established on such fissures, sometimes of considerable size, with the usual accompaniments of volcanic eruptions. He contended that there was not the slightest evidence of any great central volcano of the type of Vesuvius or Etna in any part of the Western Islands, but that the vents had been numerous, widely scattered, and, on the whole, of small size.

It would be impossible to discuss all the details of Prof. Judd's paper, and if he had not replied to all the points now raised it was not from inability to do so. He entered into such discussions with much reluctance, and though he regretted having to differ so greatly from Prof. Judd, he felt himself entitled to make known the conclusions to which the researches of so long a series of years had finally conducted him.

The AUTHOR agreed with Dr. Geikie on one point, namely, reluctance to enter upon this controversy, which had been forced upon him. It was perfectly true that Dr. Geikie had published many papers on the district in question before his own appeared in 1874; but the views maintained in all these papers were utterly irreconcilable with those which were enunciated by himself, and which were now adopted by Dr. Geikie. The key to his own explanation of the structure of the district was the recognition of the intimate relations between the gabbros and the basalts; while Dr. Geikie had always held that the former were of metamorphic origin and of Laurentian age, and the latter were regarded by him at first as Jurassic, and afterwards as Tertiary lavas.

The sketch-map of Mull, as he had stated when he published it, was necessarily diagrammatic, inasmuch as the district was one of great complexity, of which no reliable topographical maps were at the time in existence. But he maintained its general accuracy; the contrasts between it and the map exhibited by Dr. Geikie were largely due to differences in the system of rock-nomenclature and the scheme of colouring employed in the two cases.

13. *On* PREVAILING MISCONCEPTIONS REGARDING *the* EVIDENCE *which we ought to expect of* FORMER GLACIAL PERIODS. By JAMES CROLL, LL.D., F.R.S. (Read January 23, 1889.)

(Communicated by Prof. BONNEY, D.Sc., LL.D., F.R.S., F.G.S.)

WITHIN the whole range of geological science there is perhaps not a point on which a greater amount of misapprehension prevails than in regard to the evidence which we ought to expect of former glacial periods. The imperfection of geological records is far greater than is generally believed—so great, indeed, that the mere absence of direct geological evidence can hardly be regarded as sufficient proof that the conclusions derived from astronomical and physical considerations regarding former ice-periods are improbable. Nor is this all. Not only are the geological records of ancient glacial conditions imperfect, but this imperfection follows as a natural consequence from the principles of geology itself. There are not merely so many blanks or gaps in the records, but a reason exists in the very nature of geological evidence why such breaks in the record might naturally be expected to occur.

The evidence of Glaciation is to be found chiefly on Land-surfaces.—It is on a land-surface that the principal traces of the action of ice during a glacial epoch are left, for it is there that the stones are chiefly striated, the rocks ground down, and the Boulder-clay formed. But where are all our ancient land-surfaces? They are not to be found. The total thickness of the stratified rocks of Great Britain is, according to Professor Ramsay, nearly fourteen miles. But from the top to the bottom of this enormous pile of deposits there is hardly a single land-surface to be detected. Patches of real old land-surfaces of a local character may, indeed, be found, as, for example, the dirt-beds of Portland; but, with the exception of coal-seams, every general formation has been accumulated under water, and none but the under-clays ever existed as a land-surface. And it is here, in a general formation, that the geologist has to collect all his information regarding the existence of former glacial epochs. The entire stratified rocks of the globe, with the exception of the coal-beds and under-clays (in neither of which would one expect to find traces of ice-action), consist almost wholly of a series of old sea-bottoms, with here and there an occasional freshwater deposit. Bearing this in mind, what is the sort of evidence which we can now hope to find in these old sea-bottoms of the existence of former ice-periods?

All geologists of course admit that the stratified rocks are not old land-surfaces, but a series of old sea-bottoms formed out of the accumulated material derived from the degradation of primeval land-surfaces. And it is true that all land-surfaces once existed as se bottoms; but the stratified rocks consist of a series of old sea-bottoms

which never were land-surfaces. Many of them no doubt have been repeatedly above the sea-level, and may once have possessed land-surfaces; but these, with the exception of the under-clays of the various coal-measures, the dirt-beds of Portland, and one or two more patches, have all been denuded away. The important bearing which this consideration has on the nature of the evidence which we can now expect to find of the existence of former glacial epochs has certainly been very much overlooked.

If we examine the matter fully, we shall be led to conclude that the transformation of a land-surface into a sea-bottom will probably completely obliterate every trace of glaciation which that land-surface may once have presented. We cannot, for example, expect to meet with polished and striated stones belonging to a former land-glaciation; for such stones are not carried down bodily and unchanged by our rivers and deposited in the sea. They become broken up by subaerial agencies into gravel, sand, and clay, and in this condition are transported seawards. Even if we supposed it possible that the stones and boulders derived from a mass of till could be carried down to sea by river-action, still these stones would certainly be deprived of all their ice-markings, and become water-worn and rounded on the way. Prof. James Geikie states that the great accumulations of gravel which occur so abundantly in the low grounds of Switzerland, and which are, undoubtedly, merely the re-arranged materials originally brought down from the Alps as till and as moraines by the glaciers during the glacial epoch, rarely or never yield a single scratched or glaciated stone. The action of the rivers escaping from the melting ice has succeeded in obliterating all trace of striæ. It is the same, he says, with the heaps of gravel and sand in the lower grounds of Sweden and Norway, Scotland and Ireland. These deposits are evidently in the first place merely the materials carried down by the swollen rivers that issued from the gradually melting ice-fields and glaciers. The stones of the gravel derived from the demolition of moraines and till have lost all their striæ and become in most cases well rounded and water-worn. Further, we cannot expect to find Boulder-clay among the stratified rocks; for Boulder-clay is not carried down as such and deposited in the sea, but under the influence of the denuding agents becomes broken up into soft mud, clay, sand, and gravel, as it is gradually peeled off the land and swept seawards. Patches of Boulder-clay may have been now and again forced into the sea by ice and eventually become covered up; but such cases are wholly exceptional, and their absence in any formation cannot fairly be adduced as a proof that that formation does not belong to a glacial period.

It may, however, be replied that there is one kind of evidence of former glacial periods which we ought to expect in the stratified rocks, viz., the presence of large erratic blocks imbedded in strata which, from their constitution, have evidently been formed in still water. But even allowing this to be the case, we cannot regard the absence of such blocks as proof that no glacial period occurred during the time of the formation of the strata; for their mere

absence may be the indication either of a period of extreme glaciation or of a period absolutely free from ice. This absence is a result which would as truly follow from the former condition of things as from the latter. Glaciers carry erratic blocks on their surfaces, but such blocks are seldom, if ever, on the surface of an ice-sheet. The reason is obvious. When a country is completely buried under ice there is no source from which the ice can obtain erratics on its surface. The stones which lie under the ice, before they can reach the sea, are ground down to powder. Large erratic blocks have never been found, for example, on the ice-sheet of Greenland. No one, of course, has as yet had an opportunity of examining the surface of the Antarctic ice; but judging from the character of the icebergs derived from it, we are almost certain that it contains no boulders. Were the seas surrounding these continents elevated into dry land, a geologist, judging from the comparative absence of boulders in the sedimentary deposits which have been forming for the past thousands of years, would be apt to conclude that these continents had never been covered by ice. In fact, a conclusion of this kind has been arrived at by Prof. Nordenskjöld, who maintains, because he has never seen in the strata of Greenland or Spitzbergen a boulder larger than a child's head, that down to the termination of the Miocene period no glacial condition of things existed in these regions—a conclusion most certainly utterly erroneous. Now both of these lands are at present in a state of glaciation; and were it not for the enormous quantity of heat which is constantly carried northwards from the equatorial regions by the Gulf-stream, not only Greenland and Spitzbergen, but the whole of the Arctic regions would be far more completely under ice than they are. A glacial state of things is the normal condition of Polar regions; and if at any time, as during the Tertiary age, the Arctic regions were free from snow and ice, it could only be in consequence of some peculiar distribution of land and water and other exceptional conditions. That this peculiar combination of circumstances should have existed during the whole of that immense lapse of time between the Silurian and the close of the Tertiary period is certainly improbable in the highest degree: in short, that Greenland during the whole of that time should have been free from snow and ice is as improbable, although perhaps not so physically impossible, as that the interior of that continent should at the present day be free from ice and covered with luxuriant vegetation.

In fact, it is the severity of glacial conditions in these regions during glacial periods that has rendered the strata to which Prof. Nordenskjöld refers so comparatively free from erratic blocks. Had these regions been occupied by glaciers reaching to the sea, instead of being covered by a sheet of ice, boulders in the strata would no doubt have been far more common.

As evidence of former glacial periods we may, however, expect to find in temperate regions erratic blocks, imbedded here and there in the stratified rocks, which may have been transported by icebergs and dropped into the sea. But unless the glaciers of such epochs

reached the sea, we could not possibly possess even this evidence. This sort of evidence, when found in low latitudes, ought to be received as evidence of the existence of former glacial epochs, and, no doubt, would have been so received had it not been for the erroneous idea that, if these blocks had been transported by ice, there ought in addition to have been found striated stones, Boulder-clay, and other indications of the agency of land-ice.

It is, of course, by no means the case that all erratics are transported by masses of ice broken from the terminal front of glaciers. The "ice-foot" formed by the freezing of the sea along the coasts of the higher latitudes carries seawards quantities of blocks and *débris*. Again, stones and boulders are frequently frozen into river-ice, and when the ice breaks up in spring are swept out to sea, and may be carried some little distance before they are dropped. But both these cases can occur only in regions where the winters are excessive; nor is it at all likely that such ice-rafts will succeed in making a long voyage. If, therefore, the erratics occasionally met with in certain old geological formations in low latitudes were really transported from the land by an ice-foot or a raft of river-ice, we should be forced to conclude that very severe climatic conditions must have obtained in such latitudes at the time the erratics were dispersed.

Why we now have, comparatively speaking, so little direct evidence of the existence of former glacial periods will be more forcibly impressed upon the mind if we reflect how difficult it would be in a million or so years hence to find any trace of what we now call the glacial epoch. The striated stones would by that time be all, or nearly all, disintegrated, and the till washed away and deposited in the bottom of the sea as stratified sands and clays. And when these became consolidated into rock and were raised into dry land, the only evidence that we should probably then have that there ever had been a glacial epoch would be the presence of an occasional large block of the older rocks found imbedded in the upraised formation. We could only infer that there had been ice at work from the fact that by no other known agency could we conceive such a block to have been transported and dropped in a still sea.

Few geologists probably believe that during the Middle Eocene and the Upper Miocene periods our country passed through a condition of glaciation as severe as it has done during the Post-pliocene period; yet when we examine the subject carefully, we find that there is actually no just ground to conclude that it did not. For, in all probability, throughout the strata to be eventually formed out of the destruction of the now existing land-surfaces, evidence of ice-action will be as scarce as in Eocene or Miocene strata.

Did the stratified rocks forming the earth's crust consist of a series of old land-surfaces, instead (as they actually do) of a series of old sea-bottoms, then traces of many glacial periods might probably be detected. Nearly all the evidence which we have regarding the glacial epoch has been derived from what we find on the now

existing land-surfaces of the globe. But probably not a vestige of this will exist in the stratified beds of future ages, formed out of the destruction of the present land-surfaces. Even the very Arctic shell-beds themselves, which have afforded to the geologist such clear proofs of a frozen sea during the glacial epoch, will not be found in those stratified rocks; for they must suffer destruction along with everything else which now exists above the sea-level. There is probably not a single relic of the glacial epoch which has ever been seen by the eye of man that will be treasured up in the stratified rocks of future ages. Nothing that does not lie buried in the deeper recesses of the ocean will escape complete disintegration and appear imbedded in those formations. It is only those objects which lie in our existing sea-bottoms that will remain as monuments of the glacial epoch of the Post-tertiary period. And, moreover, it will only be those portions of the sea-bottoms that may happen to be upraised into dry land that will be available to the geologist of future ages. The point is this:—Is it probable that the geologist of the future will find in the rocks formed out of the now existing sea-bottoms more evidence of a glacial epoch during Post-tertiary times than we now do of one during, say, the Miocene, the Eocene, or the Permian period? Unless this can be proved to be the case, we have no ground whatever to conclude that the cold periods of the Miocene, Eocene, and Permian periods were not as severe as that of the glacial epoch. This is evident; for the only relics which now remain of the glacial epochs of those periods are simply what happened to be protected in the then existing sea-bottoms. Every vestige that lay on the land would in all probability be destroyed by subaerial agency and carried into the sea in a sedimentary form.

The question of the existence of former glacial periods is one on which palæontology can afford but little really reliable information. One of the main characteristics of a glacial period is the scarcity or comparative absence of plant and animal life. He certainly would be a bold geologist who would affirm, in relation to a given epoch, that because he could not find the remains of plant and animal life which he considered could have existed under glacial conditions, no glacial conditions existed during that epoch; and the more so seeing how difficult it is to determine with certainty, more especially in relation to remote periods, how much cold a plant or an animal might be able to endure.

Besides all this, supposing the organic remains of former glacial epochs were found in abundance, these remains would probably mislead most geologists. For if the theory of the glacial epoch advocated in 'Climate and Time' be correct, viz., that those epochs consisted of alternate cold and warm periods, it is evident that the greater part or nearly all of those remains would belong to the warm or interglacial periods. A geologist who did not believe in interglacial periods, judging from the character of those remains, would naturally come to the conclusion that the epochs in question were warm and equable, not glacial. This disbelief in interglacial

periods would thus induce him to give a wrong interpretation of the facts.

Assuming that a glacial epoch occurred at every time that the earth's orbit attained a very high state of eccentricity, it is quite apparent, when we reflect on the imperfection of geological records on the matter, that we have in reality about all the evidence which we could possibly expect of the existence of such epochs.

Discussion.

The President, after alluding to the speculative character of the paper, considered that the Author underrated the amount of old subaerial surface. Many freshwater deposits, such as the Wealden, were fluviatile and hence subaerial. And if glacial materials had then been in the neighbourhood they would have been preserved, as was the case in the Talchirs of India, where boulders of considerable size were deposited in fluviatile silt.

He doubted the argument about the ice-sheet yielding no erratics, and referred to the great moraine across the American continent. Moreover, further south than the ice-sheet reached, if there were mountains, glaciers would exist and would deposit stones.

Prof. Prestwich, whilst admitting the imperfection of the geological record, thought the Author's view interesting and novel, rather than convincing. If glacial periods had formerly existed we should not be dependent only on land-surfaces, but the molluscan fauna of the arctic seas, and the glacial débris and boulders spread over the bed of those seas, would bear evidence of analogous conditions. We had in India and Australia some evidence in favour of such conditions in Permian and Carboniferous times, but these even were not yet fully established; and as to Eocene and Miocene times, he would ask what evidence we had there. He knew of none. Geology furnished no evidence of periods of recurring cold such as Dr. Croll's ingenious and attractive theory required.

Mr. Evans agreed in the remarks of Prof. Prestwich. It seemed to him possible that the Author of the paper, finding a difficulty in reconciling facts with theory, suggested that the facts insufficiently represented past geological history. But whether the theory were true or not, glacial conditions must in all probability have prevailed in some parts of the globe during all periods, though probably not always in the existing centres of glaciation; and of these former glacial conditions some evidence was already forthcoming. The alleged misconceptions did not seem to him to exist, unless to a very small extent; but still Mr. Croll's communication was of great interest.

Prof. Seeley observed that geology was based on inductive evidence, but in this case it was unsatisfactory to have to deal mainly with negative evidence. As Dr. Croll has not attempted to estimate the significance and origin of the boulders which occur in many geological deposits, we are not bound to do the work for him. Every geologist admits that glaciation would be a necessary incident in any

period of time if the land were high enough. Boulders thus formed on land might be imbedded in a marine stratum when the land was subsequently depressed without indicating their age or origin. The contention for glacial periods was superfluous.

Prof. BLAKE considered that the previous average temperature was higher in a refrigerating earth. Hence there was plenty of evidence of more life in the Arctic regions in past epochs. There was a sort of negative evidence of the non-existence of successive glacial periods in the absence of the very mixed conglomerates which are produced from the disintegration of Boulder-clay with stones. The great boulders proved very little one way or the other.

Rev. E. HILL thought the paper an able one of its kind. He agreed that insufficiency of evidence must not be regarded as fatal to the theory, but on the other hand demurred to allowing that imperfection in the record could make up for deficiency of proof.

14. *On* Remains *of* Eocene *and* Mesozoic Chelonia *and a* Tooth *of* (?) Ornithopsis. By R. Lydekker, Esq., B.A., F.G.S. (Read January 23, 1889.)

[Plate VIII.]

Introductory.

The greater portion of the present communication is devoted to the consideration of Chelonia, and more especially to specimens from the Cambridge Greensand, most of which were collected nearly twenty years ago by my college friend Mr. T. Jesson, F.G.S., of Northampton. It includes, however, the description of an interesting Chelonian from the Wealden, kindly lent to me by the Rev. P. B. Brodie; and also makes certain redeterminations as to the affinities and serial position of some of the marine Chelonians of the London Clay. The tooth from the Wealden referred to *Ornithopsis* leads to the consideration of the affinities of some allied specimens from the Portlandian of France.

1. *The Genus* Rhinochelys, *of the Cambridge Greensand.*

The name *Rhinochelys* was applied in 1869 by Prof. H. G. Seeley* to the Chelonian cranium from the Cambridge Greensand figured by Sir R. Owen in his 'Cretaceous Reptilia' (Mon. Pal. Soc.), pt. i. pl. vii. a, figs. 1–3 (1851), under the name of *Chelone pulchriceps*, of which species it is the type. The distinctive features of this cranium, as shown by the figure, are that the pterygoids, which are in contact throughout their length, are comparatively narrow and emarginate, and that the palatines unite in the median line. There are, moreover, distinct nasals, the prefrontals being separated from one another by the nasals and frontals. Again, the temporal fossæ are completely roofed over, after a manner now obtaining only in the Chelonidæ—that is to say, there is both an inferior and a superior temporal arcade; the postfrontal articulates by a long suture with the parietal; and it seems, judging from other specimens, that the squamosal may have joined the parietal to form a parieto-squamosal or post-temporal bar. The whole of the tympanic area is not shown, but it appears that the tympanic ring was very largely ossified, although perhaps open inferiorly, and that, as in the Chelonidæ, the quadrato-jugal entered into the formation of this ring. Other specimens seem to show that the auditory labyrinth was completely open posteriorly, after the Pleurodiran manner. Further, there is no flooring of the narial passage, and the oral surface of the palate has a prominent ridge on either side.

In establishing the genus *Rhinochelys*, Prof. Seeley pointed out that it could not belong to the Chelonidæ, observing that "it is Emydian in its affinities, and well characterized by having the nasal and pre-

* 'Index to Aves &c. in Cambridge Museum,' p. 25.

frontal distinct; by the posterior nares being formed by the maxillary and palatine bones, and divided by the whole length of the vomer, which extends on the palate between the palatine and premaxillary bones; and by the temporal region being covered by an arrangement of bones like that in *Chelone*." This description differs from Owen's figure by the introduction of the vomer, which is not shown in the latter. Although I have not seen specimens showing the presence of the vomer, I take it, on theoretical grounds, that this element was probably present. There is unfortunately a little ambiguity in the expression employed by Prof. Seeley as to the vomer extending between the palatines and the premaxillæ, as this might mean separating the two palatines from one another; I take it, however, from the evidence of Owen's figure, that it is intended to mean that the vomer connects the palatines with the premaxillæ.

In 1873 Prof. S. Rütimeyer, who appears to have been unacquainted with the name *Rhinochelys*, on pp. 148–150 of his 'Fossile Schildkröten von Solothurn,' came to the conclusion that the skull of *Chelone pulchriceps* showed, on the whole, more affinities with the Chelydidæ than with any other family, and concluded that this form probably indicated a Pleurodiran.

With this conclusion I am disposed to agree, since, if we put aside the alleged occurrence of separate nasals in the so-called *Euclastes*, the only existing Chelonians having distinct nasals are the Chelydidæ; while, with the exception of the Trionychoidea, it is only among the Pelomedusidæ that we find the palatines uniting in the middle line. The anterior portion of the palate of *Rhinochelys* has, indeed, the same relations of the bones surrounding the posterior nares as in the existing *Pelomedusa**, with the exception that in the latter the vomer is absent. It is true that the palatines of *Rhinochelys* are much narrower than in any recent Pleurodiran, and are thereby of a Cryptodiran type; while the complete roofing over of the temporal fossæ is not found in any recent Pleurodira, the roof found in *Podocnemis* being of a totally different structure. I am, however, disposed to consider that the extremely wide pterygoids of existing Pleurodirans, together with the remarkable structure of the tympanic ring and the mandibular articulation, are characters more or less recently acquired; while the complete bony roof of *Rhinochelys* I look upon as an archaic character, since it occurs in many of the Jurassic Chelonians, some of which, like *Eurysternum*, are Cryptodiran, while others, like *Idiochelys*, are probably Pleurodiran. Remnants of this roof are, I think, to be found in the parieto-squamosal bar of many Chelydidæ. My reasons for regarding the broad pterygoids of recent Pleurodirans as an acquired character is that all Jurassic Chelonian skulls with which we are acquainted have more or less narrow pterygoids, and it is practically certain that some of these are Pleurodiran. This is well shown in the skull figured in pl. xiv. figs. 1, 2, of the above-cited memoir of Prof. Rütimeyer, which is referred with considerable probability to *Plesiochelys*. In that skull the vomer divides the palatines,

* See Boulenger, 'Catalogue of Chelonians &c. in the British Museum,' p. 198, fig. 48 (1889).

and there are no distinct nasals, but we have the same complete roofing of the temporal fossæ. Similar features are presented by the skull figured in the 'Palæontographica,' vol. xxv. pl. xvii. figs. 11, 12, as *Chelonides* (a preoccupied name), where the palatines are in contact. An example of another skull which may possibly belong to this generalized Pleurodiran type is the large one from the Portlandian, described by Sir R. Owen in the 'Rep. Brit. Assoc.' for 1841, p. 168, and figured in his 'History of British Fossil Reptiles,' vol. i. Chelonia, pl. viii. figs. 1–3, as *Chelone planiceps*. This skull differs from the one referred to *Plesiochelys* by its distinct nasals, and from that of *Rhinochelys* by the meeting of the prefrontals in a median suture, as well as by the deep notch below the jugal, and the separation of the squamosal from the parietal. This skull, I propose, should be provisionally known by the generic name of *Stegochelys* until it can be identified with a genus founded on the shell.

With regard to its distribution in time, a cranium in the British Museum (No. R. 27) indicates the occurrence of *Rhinochelys* in the Chalk Marl; while other specimens in the same collection show that it also extended downwards to the Gault.

Before proceeding to describe the species of *Rhinochelys*, reference may be made to fragments of Chelonian skulls characterized by their pustulate exterior, which are of very common occurrence in the Cambridge Greensand, and to which Prof. Seeley * has applied the name *Trachydermochelys*, but without attempting to show any justification for generically distinguishing them from *Rhinochelys*. *Primâ facie* there is, indeed, every probability that these specimens do belong to that genus, as being the commonest Chelonian in the beds in question, and apparently the only one not referable to the Chelonidæ. Specimens in Mr. Jesson's collection indicate that the carapace to which these fragments belonged had an expanded and everted border, as in many existing Pleurodira; while the pustulation of the exterior is only an exaggeration of a feature found in the living Pleurodiran genus *Chelodina*. I only put forward this view as a suggestion; but I may add that some further evidence pointing to the Pleurodiran affinity of *Rhinochelys* is afforded by a small cervical vertebra from the Cambridge Greensand, sent me by Mr. Jesson, which appears to have distinct transverse processes, like those of existing Pleurodirans.

It is possible that some of the undermentioned forms may really differ sufficiently from the type to constitute a distinct genus; but, for the present at least, I have retained the whole of them in *Rhinochelys*.

Coming now to the consideration of species, Prof. Seeley, on pp. xviii & xix of the work cited, applies no less than fifteen specific names (in addition to the type species) to remains of this genus; but since none of them have been defined, they can only be regarded as MS. names. I proceed, therefore, to define such species as I can determine from the specimens in Mr. Jesson's collection and in that of the British Museum.

* *Op. cit.* p. 33.

RHINOCHELYS PULCHRICEPS.

To the type species I refer the somewhat imperfect and rather crushed specimen represented in Pl. VIII. figs. 1, 1 *a*. This specimen agrees with the type in the following features, which may be taken as diagnostic. Skull much depressed, with prognathous muzzle, and a long interval between the latter and the tympanum; nares comparatively small and wide; nasals of moderate size and width; palatal ridges very prominent; nasal and maxillæ uniting to exclude prefrontals from nares.

RHINOCHELYS CANTABRIGIENSIS, n. sp.

The well-preserved cranium in the British Museum (No. 43980) represented in figs. 2, 2 *a* of Plate VIII. differs from that of the type species in its more vaulted contour, the less produced muzzle, and the shorter interval between the latter and the tympanum, as well as by the relatively wider nasals. I find a smaller cranium of similar type in Mr. Jesson's collection. Assuming these points to be of specific value, this form may be known under the above-mentioned name. This specimen shows that the auditory labyrinth was open posteriorly.

RHINOCHELYS MACRORHINA, n. sp.

Of this form there are numerous imperfect crania in Mr. Jesson's collection, while another in the British Museum (No. 35193), shown in fig. 7 of Plate VIII., is selected as the type. It is characterized by the premaxillæ being deeper and less prominent than in the type species, by the large and antero-posteriorly elongated nasals, the moderate-sized nares, and by the more vaulted cranium in which the frontal region is much flattened.

RHINOCHELYS ELEGANS, n. sp.

The anterior portion of a cranium represented in Pl. VIII. fig. 5 (B.M. No. 41796) apparently indicates another species, which attained somewhat larger dimensions than either of the preceding, and is characterized as follows. Allied to *R. macrorhina*, but with the nasals relatively wider and shorter, and the premaxillæ considerably deeper. The latter character causes the beak to have a decidedly hooked appearance. Skulls of the type of the next specimen also show a peculiar lateral swelling in the prefrontal region, which appears to be distinctive of this form.

The well-preserved skull shown in fig. 4 of Plate VIII. is from Mr. Jesson's collection, and apparently indicates an individual belonging to the same species as the preceding. Curiously enough, there is, however, no trace of a suture between the nasals and prefrontals, which at first led me to believe that this specimen belonged to *Chelone*. The peculiar form of the suture between the frontals and prefrontals shows, however, where the nasal suture should be; while we have the continuation of the alveolar line of the maxilla by the jugal, which is at once distinctive.

RHINOCHELYS BRACHYRHINA, n. sp.

This species is also represented by several imperfect crania. In the type specimen (Pl. VIII. figs. 3, 3 *a*) it will be seen that the cranium is readily distinguished from that of the preceding species by the extremely small size of the nasals, in which the width exceeds the length, and by the very large dimensions of the nares, as well as by the circumstance that the prefrontals enter largely into the formation of the nares. This form should perhaps represent a distinct genus.

RHINOCHELYS JESSONI, n. sp.

The almost perfect and beautiful specimen shown in Pl. VIII. figs. 6, 6 *a* indicates a sixth species characterized as follows:—The skull is much depressed, and the beak markedly hooked; the narial aperture is small, with the nasals antero-posteriorly elongated and narrowing superiorly; the prefrontals are very large, almost meet in the middle line above the nares, and enter to a small extent into the formation of the nares; while the frontals are very short and wide. The parietals are also much wider than in the other species. This skull also differs by the strongly marked impressions of the epidermal shields in the fronto-nasal region, which are liable to be mistaken for the sutures. The indistinctness of many of the sutures apparently shows that this specimen belongs to an adult individual, and consequently that the species was of smaller size than either of the preceding. There is a possibility that this species may really indicate a distinct genus. This specimen is important as showing that the squamosal, if not actually articulating with the parietal, was at all events closely approximated to that bone. The conformation of the anterior border of the tympanic ring is also very clearly displayed.

2. *Chelonidæ from the Cambridge Greensand and Gault.*

CHELONE JESSONI, n. sp.

In the above-mentioned 'Index' no mention is made of any remains from the Cambridge Greensand which are referred to the family Chelonidæ, and it is therefore of some interest to be able to bring forward evidence of the existence of apparently two genera of that family in these deposits. Of the first form I have evidence in portions of the skull—the cranial portion being from the Gault, while the mandibles, which I take as the type, are from the Cambridge Greensand. Of the cranium the British Museum possesses the palate (No. 47209) of a large Chelonian from Folkestone, which appears to be that of a Turtle, and which would accord in relative size with the larger of the undermentioned lower jaws. This palate appears to have been ridged, and in its narrow form agrees with *Chelone* rather than with *Thalassochelys.* Of the mandible there are two specimens—one in Mr. Jesson's collection, and the other in the British Museum (No. 35186). The latter, which is figured in

the accompanying woodcut, and is somewhat smaller than the example in Mr. Jesson's collection, is taken as the type of the species. From

Fig. 1.—*Lateral and Oral Aspects of the Mandibular Symphysis of* Chelone Jessoni; *from the Cambridge Greensand.* ($\frac{2}{3}$ nat. size.)

their extremely large size, I take it that these specimens are probably referable to marine Turtles, and do not belong to *Rhinochelys*, which we have no evidence to show attained anything like these dimensions. Assuming that I am right in this respect, the specimen may be described as follows:—The symphysis is considerably elongated, and the palatal surface deeply concave, with a distinct median ridge, tending to form a tubercle at its posterior extremity. Inferiorly the symphysis is deep, narrow, and highly convex. In all these respects the specimens agree very closely with the mandible of the Hawksbill; and since the palate of the above-mentioned cranium likewise approximates to that of the latter, there is a strong presumption that both the cranium and mandibles may belong to one and the same species*. The present type of mandible, it may be added, is quite different from that of *Chelone Hoffmanni* of the Maastricht Cretaceous. It remains to consider whether these specimens can be referred to any Cretaceous species already described. Now it appears to me, judging from the Ichthyopterygia and Sauropterygia, that a considerable number of the reptiles of the Cambridge

* The presence of oral ridges in one species of *Thalassochelys* renders it possible that the present form belongs to that genus.

Greensand are not specifically separable from those of the Chalk; and there is accordingly a probability that the specimens under consideration may be referable to *Chelone Benstedi* of the last-named deposit. That species is, unfortunately, known to us only by the young shell, and doubts have been raised whether it is really referable to the Chelonidæ. I have, however, no doubt that this reference is correct, and I may add that in this view I have the support of my friend Mr. Boulenger; while the contour of the carapace is unlike that of *Lytoloma*. That form differs, however, from existing species of *Chelone* in its carapace being pointed at both extremities, in which respect it agrees with *C. Hoffmanni* *. I do not, however, regard this difference as necessarily of more than specific value, and do not therefore propose at present to adopt Sir R. Owen's name of *Cimo*[*lio*]*chelys* for the species in question.

It is, of course, impossible to say whether the specimens under consideration are or are not specifically identical with *C. Benstedi*; but in the absence of any evidence of this identity, although bearing in mind how extremely undesirable it is to take different parts of the skeleton as specific types, I propose to refer them provisionally to a new species, as *C. Jessoni*.

LYTOLOMA CANTABRIGIENSE, n. sp.

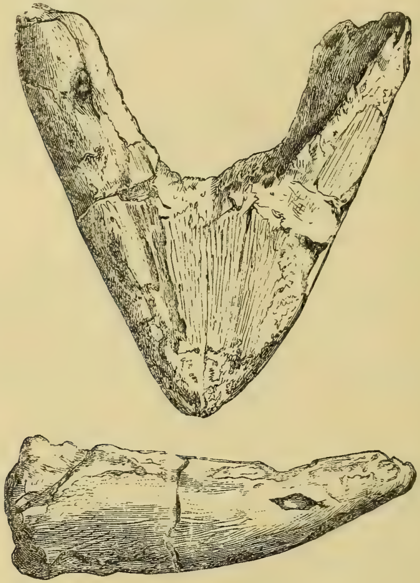
The specimens which I have now to describe are in the British Museum and comprise an imperfect mandible (No. 35178) and a humerus (No. 35175). Both were purchased at the same time, and were very probably associated; but I take the mandible as the type. The latter (fig. 2) comprises the entire symphysis and portions of the two rami. The symphysis is relatively long and wide, and is devoid of ridges superiorly, while inferiorly it is distinctly convex. The general contour of the specimen is essentially that of the Chelonidæ, and it is quite impossible that this type of mandible, which is common in the Cambridge Greensand, can have belonged to *Rhinochelys*, of which the mandible is quite different.

Taking it, then, as certain that this mandible is referable to the Chelonidæ (in which I include the Propleuridæ of Messrs. Dollo and Cope), it is clear that it cannot belong to *Chelone* or to the London-Clay Turtles mentioned below under a new generic name, since in these forms the mandible is ridged. Of genera with smooth oval surfaces to the palate and mandible we have two, namely, the one which M. Dollo terms *Euclastes*, and the existing *Thalassochelys*. Before proceeding further it is, however, necessary to mention that the name *Euclastes*, Cope (1867), is preoccupied by the name *Euclasta*, Led.†, and must therefore be discarded. M. Dollo ‡ has recently given what he considers to be the synonymy of this genus, and he employs the term *Euclastes* in place of the earlier *Osteopygis* as having been founded on the skull instead of the shell, considering

* Dr. Baur has proposed the generic term *Allopleuron* for this species.
† Verh. zool.-bot. Ver. Wien, 1855, p. 252.
‡ Geol. Mag. dec. 3, vol. v. p. 261; and Ann. Sci. Géol. Nord, vol. xv. p. 114 (1888).

that the shell alone is insufficient to afford certain generic characters. For the same reason the term *Propleura* of Cope (1870) must be rejected. We have, however, the name *Lytoloma*, Cope, based on the evidence of the mandible, and which is earlier than *Glossochelys*, Seeley (1871), which was based on the skull. There is, indeed, the name *Puppigerus*, Cope (1870). The type of that genus must be taken to be *Chelone longiceps*, Owen, as being the first-mentioned of

Fig. 2.—*Ventral and Lateral Aspects of the Imperfect Mandible of* Lytoloma cantabrigiense; *from the Cambridge Greensand.* (Nat. size.)



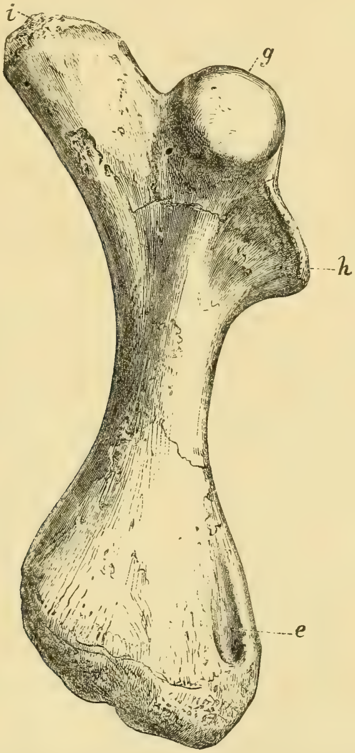
the English Eocene forms on which that genus is based. Now the skull of that form, as I have recently found, is similar to that of the young of the so-called *Chelone crassicostata*, one of the typical forms of *Euclastes*; and *Puppigerus* is therefore a synonym of the latter. The names *Lytoloma* and *Puppigerus* occur in the same volume; but since the former comes first, and the latter includes forms which are distinct, I propose to adopt *Lytoloma* in the place of *Euclastes*.

I may also mention that in young individuals, and perhaps in the adult of some of the apparently smaller forms, like *L. trigoniceps* of the Bracklesham beds, the mandibular symphysis (as shown by a specimen in the Museum of Practical Geology) is shorter and more convex than in the adult of *L. crassicostatum* and *L. planimentum*, and is thus almost similar to the mandible of *Thalassochelys*.

In these respects the present mandible agrees very closely with

the mandible of *L. trigoniceps*, and in the absence of any evidence to the contrary should apparently be referred to the same genus. The right humerus under consideration (fig. 3) differs, however,

Fig. 3.—*Dorsal Aspect of the Right Humerus of* Lytoloma cantabrigiense; *from the Cambridge Greensand.* (Nat. size.)



g, head; *h*, radial process; *i*, ulnar ditto; *e*, ectepicondylar canal.

from that of the Eocene *Lytoloma* (*Euclastes*) figured by M. Dollo, in that the head is less oblique to the shaft, and the radial process less closely connected with the head. The shaft has, however, the same marked constriction as in the latter. In the position of the head this type of humerus is, indeed, more like that of *Chelone* than of *Thalassochelys*, which approaches to the Eocene one figured by M. Dollo. Its constricted shaft separates it, however, widely from *Chelone*; and it is distinguished from both the existing genera by the solid triangular mass formed by the radial process.

I do not, however, regard these slight differences as necessarily indicating generic distinction; and I therefore propose, on the

assumption that the humerus and mandible belong to the same form, to refer them to *Lytoloma*. This view is in harmony with that of M. Dollo, who refers a very similar mandible from the Chalk, figured by Sir R. Owen in his 'Cretaceous Reptilia,' pt. i. pl. vii. A, fig. 4, to this genus (*Euclastes*) *.

With regard to specific distinction, the pointed posterior end of the carapace of *Chelone Benstedi* is different from that of the Eocene species of *Lytoloma*, in which the carapace is rounded behind; so that the presumption is that the Greensand form does not belong to that species. Under these circumstances I propose the name *Lytoloma cantabrigiense* for the latter, taking the mandible as the type.

It is possible that in this form and *L. trigoniceps* of the Bracklesham Beds we have species differing somewhat from the typical Lower Eocene forms and approximating to *Thalassochelys*.

I may observe, in passing, that humeri in the British Museum (*e. g.*, No. 35365) indicate the occurrence of Athecate Chelonians in the Cambridge Greensand, which I am disposed to refer to the American Cretaceous genus *Protostega* of Cope.

3. ARGILLOCHELYS (nov. gen.) *from the London Clay.*

I may take the opportunity of mentioning that the skull figured in pl. xv. of pt. i. of Owen's 'Reptilia of the London Clay' as the type of *Chelone cuneiceps* appears to me to indicate a form presenting affinities both with *Lytoloma*, *Thalassochelys*, and *Chelone*, but which cannot be referred to any one of these genera. I believe that the skull figured on pl. xxv. of the same writer's 'History of British Fossil Reptiles,' vol. ii. Chelonia, under the name of *Chelone convexa*, also belongs to the same species; the occipital shield (interoccipital of Owen) being thrust back in the adult. For this form I propose the generic name *Argillochelys*, of which I shall give the full description in the British Museum 'Catalogue of Fossil Reptilia;' I may mention, however, that it is chiefly characterized by the extreme shortness and anterior breadth of the pterygoids, in which the lateral borders are deeply emarginate, and the ectopterygoid processes are placed at the antero-external angles instead of near the middle of these bones. The palate and mandibular symphysis are ridged, and, at least in the young, the skull has an azygous occipital shield, as in *Thalassochelys*. I believe that other Chelonians from the London Clay described by Sir R. Owen may also be referred to this genus, and especially the skull figured under the name of *Chelone brachyceps*. Some of these forms were included by Prof. Cope in his *Puppigerus*.

4. PLESIOCHELYS (n. sp.) *from the Wealden.*

On page 272 of a paper published by Mr. G. A. Boulenger and myself in the 'Geological Magazine' for 1887, mention is made of

* Ann. Soc. Géol. Nord, vol. xv. p. 122 (1888).

the shell of a Chelonian from the Wealden preserved in the Natural History Museum, which indicates a species of the genus *Plesiochelys* so nearly allied to *P. sanctæ-verenæ*, Rütimeyer, of the Kimeridgian of Switzerland, that we were provisionally inclined to refer it to the same species.

I have lately received the loan of another Chelonian shell, belonging to the Rev. P. B. Brodie, from the Wealden of Atherfield, in the Isle of Wight, which indicates the occurrence of a second English species of *Plesiochelys*, also allied to a species from the Swiss Kimeridgian.

Of this specimen a restored view of the carapace and plastron are given in figs. 4, 5. Unluckily the neural and costal bones of the carapace have all been dislocated, and in some cases overlap one another to a certain extent; while several of the neurals and nearly all the marginals are missing. Fortunately, however, the sulci formed by the boundaries of the vertebral and costal epidermal shields are very clearly marked, and are sufficient to show the entire contour of the vertebral shields. The plastron is nearly entire, and shows the absence of a mesoplastral, by which the specimen is at once distinguished from *Pleurosternum*; the epi- and entoplastrals have been dislocated, and thrust in between parts of the broken nuchal of the carapace.

The general contour of the specimen, and especially the sinuous outline of the borders of the vertebral shields, and the distinct, oblique, longitudinal striation of the neural and adjacent portions of the costal bones, together with the four long and narrow infra-marginal shields on the plastral surface, indicate without doubt that the specimen belongs to the genus *Plesiochelys*.

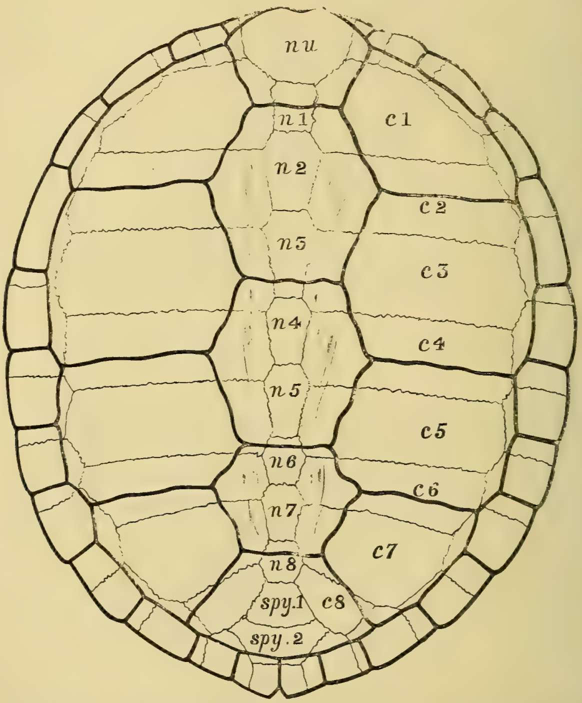
In the complete ossification of the plastron it agrees with the Kimeridgian species *P. solodurensis*, Rütimeyer *, and probably with *P. sanctæ-verenæ*, Rütimeyer †, and differs from *P. Etalloni* of the same writer, in which there is a persistent plastral vacuity. It further differs from *P. sanctæ-verenæ*, and the above-mentioned Wealden shell, by the much less strongly marked striations on the neurals and costals, which are mainly confined to the median region of the carapace; the vertebral shields are also relatively narrower. The plastron of *P. sanctæ-verenæ* is unknown; but that of the allied Wealden form is relatively shorter and wider, and connected by a longer bridge with the plastron.

Compared with Rütimeyer's figures of the upper and under surface of the male shell of *P. solodurensis* already cited, the resemblance presented by the present specimen is so exceedingly close as to leave no doubt of the near relationship of the two forms. In the English specimen the pectoral shield of the plastron is nearly as long as the abdominal, instead of being very much shorter; while the posterior border of the abdominal is much less oblique. The infra-marginals are, moreover, relatively wider in the English form. On the carapace the chief difference that can be detected between the

* Foss. Schildkröten von Solothurn, pl. xii.
† *Ibid.* pl. xiii.

two forms consists in the much narrower costal shields of *P. sanctæ-verenæ*, or, in other words, the wider vertebrals.

Fig. 4.—*Restoration of the Carapace of* Plesiochelys Brodiei ; *from the Wealden of the Isle of Wight.* $\frac{1}{4}$.



With the exception of the marginals the restoration is entirely based on the actual remains preserved.

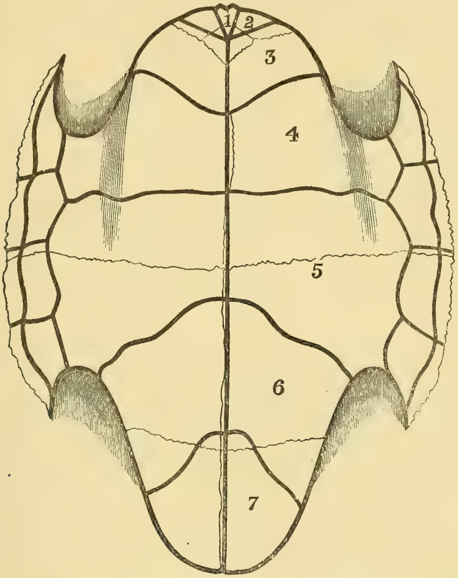
The letters *n* 1 to *n* 8 indicate the neural, and *c* 1 to *c* 8 the costal bones.

Although I am aware that the size and contour of the epidermal shields is liable to a considerable variation among existing Chelonians, and affords a somewhat unsatisfactory basis of specific distinction, yet, taking into account the constancy in the contour of the shields of the specimens described by Rütimeyer, and the wide difference in the age of the geological horizons of the Swiss and English forms, I am disposed in this instance to regard these features as of specific value. The English form may be designated, after the owner of the type specimen, *Plesiochelys Brodiei.*

On further comparison of the second Wealden shell of a *Plesiochelys* (B.M. No. 28976), I find that this specimen is distinguished from *P. sanctæ-verenæ* by its narrower costal shields, and I accordingly

propose to regard it as the type of a second Wealden species, under the name of *P. valdensis.*

Fig. 5.—*The Plastron of* Plesiochelys Brodiei. ($\frac{1}{4}$ nat. size.)



1, intergular shield; 2, gular ditto; 3, humeral ditto; 4, pectoral ditto; 5, abdominal ditto; 6, femoral ditto; 7, anal ditto.

Both *P. Brodiei* and *P. valdensis* may, in all probability, be regarded as the direct descendants of the two Kimeridgian species to which they are respectively allied, and it is interesting to note the long continuance of the two types, each represented by a Kimeridgian and a Wealden species. It is further somewhat remarkable that in both types the Wealden form differs from the Kimeridgian in the same characters.

5. Chelone gigas, *Owen, from the London Clay.*

In his 'History of British Fossil Reptilia,' vol. iii. p. 188, and vol. iv. pls. xxx., xxxi., and also in his 'Reptilia of the London Clay,' vol. ii. pls. i., ii. (1880), Sir R. Owen described a large Chelonian skull from the London Clay, under the name of *Chelone gigas.* Having had occasion recently to examine this specimen (which is in the Natural History Museum), I find that it differs *in toto* from the Chelonidæ, and agrees in all essential characters with *Dermatochelys* (*Sphargis*), this being at once shown by the absence of a floor to the nasal passage, and the consequent forward position of the poste-

rior nares, and the general contour of the bones of the palate and occiput, which are totally different from those of the Chelonidæ; similarly, in the upper surface of the skull the peculiar upward direction of the nares, and the thin bar separating them from the large orbits, both of which are characteristic features of *Dermatochelys*. A second skull in the Museum exhibits, moreover, the absence of descending parietal plates which distinguish the skulls of this group from those of all other Chelonians. Further evidence is afforded by a humerus attached to the block in which this skull is imbedded, which is of the same general type as that of the undermentioned extinct genus.

The skull is much flatter and wider than that of the existing genus, and in this respect it agrees with the description given by M. Dollo* of the Miocene and Upper and Middle Eocene genus *Psephophorus*, an extinct representative of the Dermatochelydidæ. For the present, therefore, until I have investigated into the structure of the carapace, I propose to refer the Lower Eocene form to the latter genus.

[Note, *February* 1889.—Since the above was written, I have made, in company with M. L. Dollo and Mr. Boulenger †, a careful examination of the mass of rock ‡ described by Sir R. Owen in the memoir cited, which contains the bones of the pectoral girdle and portions of the ribs and carapace of this form. The remains contained in this mass of rock are stated by Sir R. Owen to have been associated with the figured cranium; but although this is not the case, there is no doubt that these bones belong to the same form, since there is associated with them the distal portion of a humerus § corresponding exactly with the entire humerus attached to the unfigured cranium. It was on the evidence of this specimen that Sir R. Owen relied in referring the species to *Chelone* rather than to the Dermatochelyidæ.

The six or seven large and transversely elongated bony plates lying on the dorsal surface of the ribs of this specimen were described by Sir R. Owen as neural bones. In addition, however, to their wide difference in form from the neurals of any known Testudinata (Thecophora) it can at once be shown that this interpretation is incorrect, since three of them overlie two ribs. Again, at that extremity of the specimen where they overlie the ribs they can distinctly be seen to form a separate layer; while at the other extremity of the slab they are not underlain by ribs at all. This clearly shows that these plates are merely dermal ossifications, which from their position evidently formed a median dorsal series. The total absence of polygonal tesseræ like those of *Psephophorus* in this slab, and also in

* Bull. Mus. R. Hist. Nat. Belg. vol. v. p. 59 *et seq.* (1883); also Ann. Soc. Sci. Brux. 1887, p. 139 *et seq.*

† I am greatly indebted to these gentlemen in regard to the determination of the real nature of the carapace in this specimen.

‡ B.M. No. 44089.

§ B.M. No. 44090.

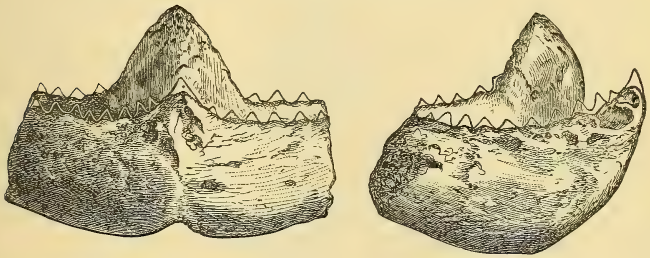
the matrix containing the unfigured skull and associated bones, leads to the conclusion (as suggested to me by M. Dollo) that the carapace of this form consisted only of the median row of ossifications, together with a series of marginals. M. Dollo also states that, although the cranium is very like that of *Psephophorus*, yet there are certain differences, and more especially the apparent absence in the premaxillæ of the descending process found in that genus and *Dermatochelys*.

Under these circumstances, I am disposed to regard *Chelone gigas* as indicating a new genus of Dermatochelyidæ, for which I propose the name *Eosphargis*, and which may be briefly defined as follows:—Skull and humerus of the general type of *Psephophorus*; carapace consisting of a median dorsal row of large carinated plates, of which the width largely exceeds the length, and probably also of a series of large marginals.]

6. Dacochelys (n. gen.) *from the London Clay.*

Among the numerous remains of Chelonians from the London Clay in the British Museum is the imperfect anterior extremity of the mandible of a large form (No. 39257), hitherto placed with the Chelonidæ, but which has evidently nothing to do with that group. The whole of the symphysis is nearly entire, and affords very distinctive characters. The outer alveolar ridge is, indeed, somewhat broken, but sufficient remains to show that it was elevated mesially into a sharp point,

Fig. 6.—*Restoration of the Anterior Extremity of the Mandible of* Dacochelys Delabechei, *viewed from in front and from the right side; from the London Clay.* (⅔ nat. size.)



while laterally it had a number of tooth-like processes similar to those in the Batagurs and in *Testudo elephantina*. This character at once distinguishes the specimen from all members of the Chelonidæ, in which the alveolar borders of the jaws are invariably smooth. Within this alveolar ridge is a deep groove, succeeded inwardly by a second ridge, which appears to have been likewise serrated, and is higher than the outer one. In the middle line the inner ridge is developed into a huge triangular process, projecting far above the

level of either of the two ridges, which is evidently the representative of the much smaller process found at the hinder border of the mandibular symphysis of the Hawksbill Turtle.

No existing Chelonian has anything like this extraordinary development of this process as seen in the present specimen; and it is quite evident that the cranium of the form to which this mandible pertained must have had a deep pit on the oral surface of the palate for the reception of the spine-like process. It may further be concluded that our specimen indicates a Chelonian of herbivorous habits.

The Chelonians having serrated alveolar borders to the mandible having been mentioned, it will be well to show how they differ from our specimen. Firstly, with regard to *Testudo elephantina*, the symphysis is so much shorter, and the whole contour is so different, that it is quite clear that our specimen does not indicate a type in any way allied. Compared with the Batagurs (*Hardella, Kachuga*, &c.) there is somewhat more resemblance; but in that group the inner ridge of the symphysis is always lower than the outer, and in neither of the genera is the contour of the whole symphysis like the present specimen. In the Carnivorous Testudinidæ the mandibular symphysis differs very widely from the latter.

Among existing forms the type of mandible which seems to come nearest to the fossil is that of the genus *Podocnemis*, the sole existing herbivorous genus among the Pleurodira. This resemblance is noticeable in the whole general contour of the symphysis, and especially in the circumstance that the inner ridge is higher than the outer. It is true that *Podocnemis* has no serrations on the ridges, nor a median process like that of the present specimen, but these might be merely generic differences.

Having, then, decided that the specimen under consideration indicates a large Chelonian generically distinct from any existing type, but apparently showing resemblances to *Podocnemis*, we have to face the problem whether it can be identified with any of the forms hitherto described from the London Clay. Now the Chelonia of those beds comprise, in the first place, certain Dermatochelydidæ, Chelonidæ, and Trionychidæ; and it is quite clear that our specimen has no affinity with either of these three families. Next we have the genus *Pseudotrionyx*, of which the full affinities are unknown, but which appears to be more or less closely allied to the carnivorous Chelydridæ. If this view be correct, there will be little doubt that our specimen is not referable to *Pseudotrionyx*.

There is, however, more satisfactory evidence to show that the present specimen is not referable to *Pseudotrionyx*. The imperfect skull figured in plate xxxix. figs. 1, 2, of Owen's 'Reptilia of the London Clay,' and provisionally referred to the Pleurodiran genus *Platemys*, has recently been cleaned from matrix, and found not only to be Cryptodiran, but to be essentially Chelydroid. Now, since *Pseudotrionyx* is Chelydroid, it is practically certain that this skull belongs to that genus. The alveolar margins of that specimen are entire, and the whole character of the skull agrees very closely in general features with that of the existing *Macroclemmys*.

Of the other Chelonians of the London Clay the only form which attains dimensions corresponding to that of the jaw before us is the species described by Sir R. Owen as *Emys Conybeari*, which has been shown by Mr. Boulenger and myself, in a paper published in the 'Geological Magazine'*, to be a Pleurodiran, and specifically identical with the so-called *Emys Delabechei*. From the marked resemblance of its shell to that of *Podocnemis*, we provisionally referred the species to that genus as *P. Delabechei*. Now we have already seen that the mandible before us presents a certain resemblance to that of *Podocnemis*, and there is accordingly a strong presumption that it may belong to the last-mentioned species, which in that case will not be referable to *Podocnemis*. It is, of course, impossible to be certain of this identity; and since, if I am right in considering that it is not referable to *Pseudotrionyx*, our specimen indicates a new genus, I propose to regard it as the type of one under the name of *Dacochelys Delabechei*. If this mandible be identical with the so-called *Emys Delabechei*, then Owen's specific name will stand for both, but if not, the present specimen will indicate also a new species.

7. *Tooth of* (?) ORNITHOPSIS *from the Wealden.*

In fig. 4, plate iii. of the preceding volume of the Society's 'Journal,' I figured the tooth of a Sauropodous Dinosaur from the Wealden of the Isle of Wight, which I considered might probably be referable to *Ornithopsis* (or *Pelorosaurus*, if the two be identical and

Fig. 7.—*Inner surface of the crown of a Tooth of* (?) Ornithopsis; *from the Wealden of Kent.* (Nat. size.)

we employ the earlier name). Recently, Mr. R. Etheridge showed me the crown of a tooth collected by Mr. Willett from the Wealden of Kent, which I at once recognized as of the same type as the above-mentioned specimen. This specimen (fig. 7) I think worthy of notice as being the only other example known to me, and as

* Decade 3, vol. iv. pp. 274, 275 (1887).

having led me to recognize that the teeth mentioned below are referable to the same suborder.

The present specimen is somewhat more worn at the summit and at the edges than the preceding example, and also differs slightly in contour from the latter. These differences are, however, not greater than might reasonably be expected to occur in teeth from different parts of the jaw of one and the same species; but I do not desire to press the point of specific characters one way or the other. That which, however, has especially interested me in that specimen is its general resemblance to teeth from the Portlandian of Boulogne, which have been described and figured, firstly under the name of *Neosodon*, and subsequently as *Caulodon*. The type of the former is figured by Count de la Moussaye in a paper published in 1885 *; and consists of the worn crown of a large tooth, having a transverse diameter of one and a half inch. A comparison of this figure with the figures of the two English teeth from the Wealden shows at once that the three belong to closely allied forms, although the English specimens are only one inch in diameter. This general identity is manifest by the general spatulate contour of the crown, with the concave inner and convex outer surface, and the truncate inverted V, formed by the worn summit and margins. Count Moussaye makes no suggestion as to the affinity of his *Neosodon*, beyond saying that the tooth appeared to be somewhat intermediate between the teeth of *Iguanodon* and *Megalosaurus*.

The next communication on the subject which I have to notice is one recently published by Dr. E. Sauvage, who describes and figures† other teeth from the Portlandian of Boulogne which are similar to the type of *Neosodon*. M. Sauvage, however, identifies them with a tooth previously described by himself as *Iguanodon precursor* ‡, and on the verbal evidence of Prof. Cope refers them to the genus *Caulodon*, founded by the latter writer on specimens from the Upper Jurassic of North America. As to whether the latter reference is or is not correct, I have nothing to say, because, so far as I am aware, the teeth of the typical *Caulodon* are not figured, and I know not whether that genus is distinct from all of those described by Prof. Marsh.

When, however, M. Sauvage proceeds to say that these teeth indicate a member of the Iguanodontidæ, he is clearly mistaken, since there can be no question but that they are of the general type of the above-mentioned English teeth, which are undoubtedly Sauropodous. It is quite probable, indeed, that they may be referable to *Ornithopsis humerocristatus* § of the Kimeridgian of Weymouth, or to a closely-allied form. And here I take the opportunity of correcting an error in my previously quoted paper, into which I was led by a mistaken interpretation of a figure in one of Prof. Marsh's memoirs. I there referred the vertebræ from the Kimeridgian of

* Bull. Soc. Géol. France, sér. 3, vol. xiii. p. 51, fig. 1 (1885).
† *Ibid.* sér. 3, vol. xvi. p. 626, pl. xii. figs. 1–4 (1888).
‡ See also Dollo, Rev. Quest. Sci. vol. xvii. p. 627.
§ = *Cetiosaurus humerocristatus*, Hulke; *vide* Q. J. G. S. vol. xliv. p. 57.

Swindon, described by Sir R. Owen as *Bothriospondylus suffosus*, to the Theropoda; but they are undoubtedly those of a young Sauropodous Dinosaur, and from their general resemblance to the vertebræ of the Wealden *Ornithopsis* may be referable to *O. humerocristatus*.

On the other hand there is a possibility that the teeth in question may be allied to the Kimeridgian form represented by the vertebra in the Cambridge Museum, to which Prof. Seeley has applied the name of *Gigantosaurus*, and which is apparently different from the vertebræ of *Ornithopsis*. I may observe, however, that I have great hesitation in deciding whether that name ought to be adopted; firstly, because the type has never been figured; and secondly, because the name *G. megalonyx* is clearly applicable to the ungual phalangeal which is mentioned with the vertebra, but which may equally well, as I have indicated, in pt. i. of the British Museum 'Catalogue of Fossil Reptilia and Amphibia,' belong to *Ornithopsis humerocristatus*.

Passing to an older deposit, two teeth of smaller size, but of precisely the same general type, from the Forest Marble of Wiltshire have been figured by Sir R. Owen * under the name of *Cardiodon rugulosus*. Since, according to Prof. Prestwich, the remains of *Cetiosaurus oxoniensis* in the Oxford Museum were mainly obtained from the Forest Marble, and not from the Great Oolite, it is highly probable that the tooth in question is referable to that species. I am unable to determine the exact date of publication of the name *Cardiodon*; but the specific name *rugulosus* is much earlier than Phillips's *oxoniensis*, and ought to replace the latter if the two forms be identical.

[Addendum.—Since the above was written, Mr. C. D. Sherborn, F.G.S., has given me a reference to the dates of publication of Owen's 'Odontography.' It thus appears that part i., containing plates i., ii., and 1–48, was published in 1840; pt. ii., with plates 49–87 in 1841; and pt. iii., with plates 87 *a*–150, in 1845. The name *Cardiodon* is therefore of earlier date than *Cetiosaurus*, which appeared in the 'Rep. Brit. Assoc.' for 1841, published in 1842. I may also add that the tooth mentioned above as being figured under the name of *Ornithopsis* had, in 1852, been made the type of *Hoplosaurus armatus*, Gervais, a name of earlier date than *Ornithopsis*.—*March*, 1889.]

EXPLANATION OF PLATE VIII.

Crania of *Rhinochelys*, from the Cambridge Greensand.

Figs. 1, 1 *a*. *R. pulchriceps*.
2, 2 *a*, 2 *b*. *R. cantabrigiensis*.
3, 3 *a*. *R. brachyrhina*.
4. *R. elegans*.
Figs. 5, 5 *a*. *R. elegans*.
6, 6 *a*, 6 *b*. *R. Jessoni*.
7. *R. macrorhina*.

All the figures are of the natural size. The originals of figs. 1, 2, 5 are in the British Museum, the others in the collection of T. Jesson, Esq.

pmx, premaxilla; *mx*, maxilla; *n*, nasal; *pr.f*, prefrontal; *fr*, frontal; *pt.f*, postfrontal; *pa*, parietal; *sq*, squamosal; *q.j*, quadratojugal; *j*, jugal.

* Odontography, p. 291, pl. lxxv. A. fig. 7 (1840–45).

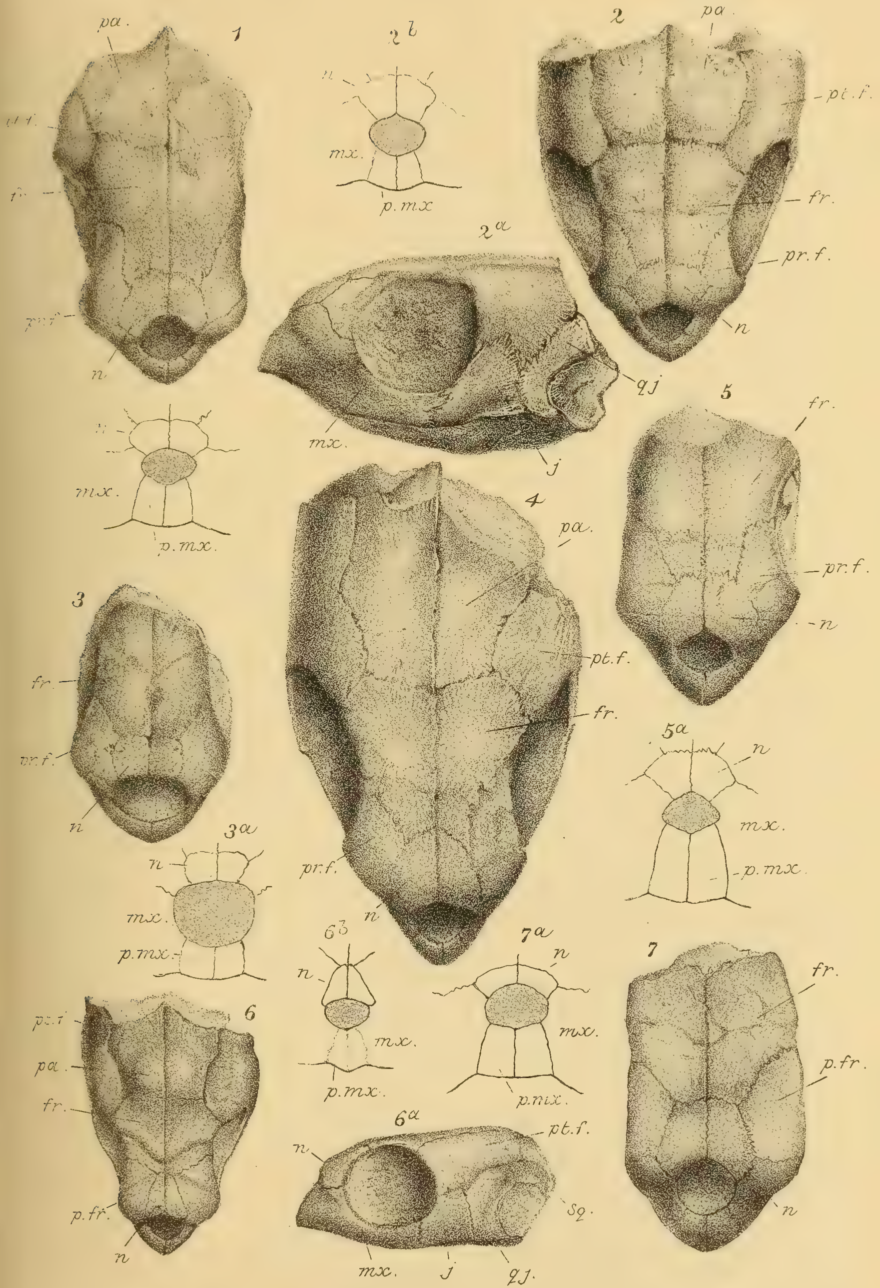
Discussion.

Prof. Seeley remarked on the difficulty of the subject; he had himself deferred writing upon it in detail, and considered that details were not sufficiently numerous for the purpose of generalization. He believed his published conclusions were very similar to Mr. Lydekker's, as regards general interpretation. In some details he differed from the Author. The fragment of marginal plate of *Trachydermochelys*, which Mr. Lydekker referred to *Rhinochelys*, was a case in point. He had much of the skeleton of *Trachydermochelys*, which showed different family affinities. His evidence was preserved in the collections of the Woodwardian Museum. He (Prof. Seeley) had long been acquainted with a Leathery Turtle from the London Clay, but he considered the specimen too imperfect for description. He was disposed to accept the identification of the tooth exhibited as belonging to *Ornithopsis*. Its occurrence in Kent was the more interesting; doubts had been expressed as to the Sussex vertebræ of *Ornithopsis* belonging to the same genus as *Ornithopsis Hulkei*. He might be excused for not entering further into a discussion of questions which were very technical.

Mr. Boulenger congratulated the Author on the useful work he was carrying out amongst the fossil Chelonia, especially as regards their zoological position. Considering that one has usually to deal with mere detached skulls and fragments of shells, and hardly ever with cervical vertebræ, the work was one of great difficulty. But he was glad to hear that Prof. Seeley had nearly perfect skeletons of *Rhinochelys*, as these would solve the still somewhat doubtful question of the systematic position of that genus.

Prof. Seeley did not wish it to be understood he had complete skeletons, but very large portions of individual skeletons. He had cervical vertebræ, which were abundant in the Cambridge Greensand.

The Author, in reply, observed that there was a possibility that some of the skulls of *Rhinochelys* were associated with the shells described as *Trachydermochelys*, and he was justified in provisionally suggesting the identity of the two forms until Prof. Seeley had proved their distinctness.



C. Berjeau lith. Hanhart imp.

CRANIA OF RHINOCHELYS.

15. *On some* Nodular Felstones *of the* Lleyn.

By Catherine A. Raisin, B.Sc. (Read February 20, 1889.)

(Communicated by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.)

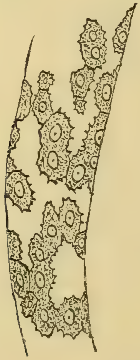
In the descriptions which have been given of various igneous rocks from the Lleyn, no details have, I believe, been published of the two small outcrops near Pwllheli, to which this paper refers. Some specimens, which I collected in 1885, I showed to Professor Bonney, and, at his suggestion, I tried to make a more thorough examination of the rocks. The two masses rise, like small islands, from the drift-covered plain around, and project seawards in the headlands of Pen-y-chain and Careg-y-defaid. They are marked on the Survey map as consisting of intrusive felspar porphyry with agate nodules. I propose, first, to describe the general types of rock, and, secondly, to notice certain structures, especially those connected with the nodules.

I. General Succession and Age of the Rocks.

At Pen-y-chain the rocks show distinct evidence of stratification, and the beds seem, on the whole, to dip about N.N.E., although with irregularities, such as might be expected in volcanic masses. Thus the lowest strata which I reached were the rocks near the south or south-westerly point. They form the seaward part of the cliff, against which the long beach from Pwllheli terminates. The rock is darkly veined, with subangular fragments of whitish felstone,

which shows faint indications of fluidal structure and contains porphyritic felspar and quartz. This rhyolitic rock seems to have undergone a brecciation *in situ*; for some of the neighbouring fragments were evidently once continuous, and the blackish veins fade off at places and are lost in the felstone. The brecciation dies out in the beds above, and the last traces of the veining consist of more regular lines joining darkened knots, which prove to be porphyritic crystals, surrounded and penetrated by the dark granular deposit. This deposit similarly aggregates around and within the crust of nodules which occur along one band. The dark lines form curves of large radius, tangential to the rock-laminæ, or to the surfaces of porphyritic crystals, as if due to perlitic contraction acting under constraint. Along the curves within one quartz grain the deposit has formed very minute scales of an irregular stellate appearance, possibly a kind of radial or dendritic development (fig. 1).

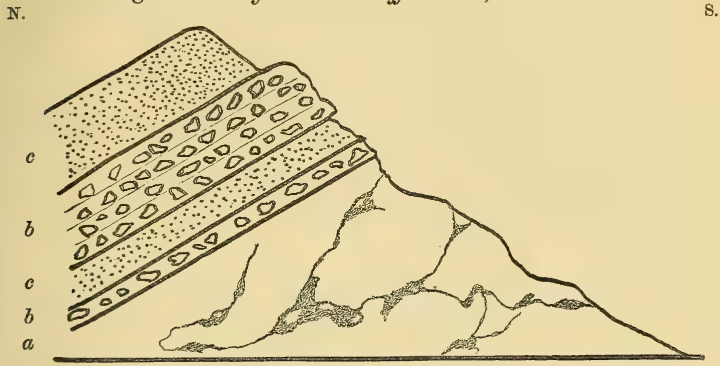
Fig. 1.—*Chains of Stellate Spherulitoid Enclosures along the curved surface of a crack, which crosses a clear porphyritic quartz-grain; the crack seems probably due to perlitic contraction. From quartz-felsite of Pen-y-chain, above brecciated rock.* (Enlarged 350 diameters.)



Along the next beach to the eastward, which is the most southerly of the district, some of the lowest rocks are of the brecciated character described. Certain bosses below high-water mark consist of a very compact, ill-mixed, pink and grey felsite, with flecks of pyrites. On surfaces smoothed by the waves are small curved furrows, like indentations of finger-nails widened irregularly by weathering. These would seem to be perlitic cracks, which the microscope shows to be abundant in the rock and even in its porphyritic quartz. The face of the cliff, which is about in the line of strike, exposes horizontal, ashy and agglomeratic layers. The dip is northerly, about 35° (fig. 2). The fragments in the agglomerate may be as much as six inches in length. Some are of slate; many,

especially the larger, are of felsite, resembling, lithologically, the neighbouring rocks; thus, one fragment exhibits part of a large radialized structure within a spherulitic matrix.

Fig. 2.—*Pen-y-chain. Cliff-section, south beach.*



a. Compact rhyolitic rock with brecciated veins. *b.* Agglomerate. *c.* Ashy beds.

The great mass of the Pen-y-chain felsite which follows consists of a compact brownish rock, including small porphyritic quartz and felspar. The rock is markedly fluidal, and the weathered surface has a slaggy look. The microscope-slides exhibit small elongated nests of clear intercrystallized grains, showing in a few cases a shaded spherulitic cross when viewed in polarized light. Some, at least, of these aggregations appear to be filled-up cavities of the lava. The bordering quartz is radial in its arrangement and often pyramidal; the cavities are ranged in irregular bands parallel with the flow, and one is bent around the corner of a large felspar at a little distance from it.

By the third beach, going northward, brecciated rock occurs, possibly a repetition of that first described. Around the point of Craig-y-baredy, some of the rock weathers rough and vesicular, but others of the old lavas, now much silicified, seem to have been more homogeneous, and lines of incipient spherulites mark the even flow, diverted at places around included crystals, which contain alteration-products of chalcedony and viridite. The coast-section of the rocks ends here against low sandy cliffs.

Inland, over the promontory, are many bosses of bare rock, and at two places it has been quarried. It is mainly felsite, compact and silicified, often breaking with a subconchoidal fracture. Some of the fresh rock is grey and flinty-looking, at other places it has alternating pinkish and greyish bands. The fluidal character, moreover, is often well developed by weathering as a furrowing of the surface.

Rocks from Pen-y-chain reminded me, lithologically, of Welsh felsites of Bala age, and the neighbouring district is classed as

belonging to that formation; but the nearest fossiliferous outcrop recorded is distant two or three miles. The country around is drift-covered, but I found some indications of stratigraphical position near the streamlet which flows to Llym-gwyn. Felsite of the usual type occurs close by the cottages, although further south, just beyond the railway, is one outcrop, which seems probably an ash, consisting of broken felstone and some slate. Walking northward for about thirty yards, along the path east of the stream, we pass over a small exposure of a peculiar black and white rock, which has a squeezed look. The milk-white fragments of felstone exhibit, under the microscope, traces of banding, possibly fluidal; they are, at places, spherulitized, and contain abundant microliths or globulites. Slaty fragments are entangled, which are often rounded, and some are beginning to crack along curving boundaries. This rock seems to be a volcanic agglomerate, which has become schistose from pressure.

Along the next 200 yards, well-banded ashy and slaty beds occur here and there, in which I found a few small fossils. These were several squeezed examples of *Trinucleus concentricus*, small specimens of *Leptæna sericea*, a distorted *Orthis elegantula*, and other young forms of *Orthis* (sp.?). This assemblage has a Bala facies, and Mr. Etheridge, who very kindly identified some of the specimens for me, gave his opinion, from the fossil and lithological characters, that the strata may be taken as belonging, in all probability, to that formation. The microscope shows quartz and plagioclase felspar in small angular fragments and a minute secondary mineral; the meshwork of dark cleavage-planes crosses the beds almost at right angles.

Some 30 yards succeed, occupied by a felspathic rock, part of which forms two small craglets overlooking the stream. The beds, although uniform, are well marked, dipping about N.N.E. at an angle of 45° or 50°. They are crossed by a cleavage similar to that of the slaty and ashy strata, and the subsequent pressure, which thus modified the rock, doubtless caused the fracturing of the included felspar. The appearance of the slide is suggestive, as Professor Bonney pointed out to me, of a very porphyritic rhyolite, now devitrified and crushed.

The next outcrop is of a compact pale grey rock, which proves to be a felstone, enclosing small fragments of slate, quartz, and felspar. The fluidal layers are much contorted, and exhibit a deposit of a minute secondary mineral.

Thus the Pen-y-chain felsites seem to pass upward into a series of agglomerates and lavas, with interbedded slates and grits, including Bala fossils. If the igneous strata of the Snowdon district once extended over the Lleyn, as suggested in the Survey Memoir *, the Pen-y-chain mass may be a remnant of such volcanic accumulations.

The small area of Careg-y-defaid does not need separate detailed description. A fine fluidal structure in a porphyritic rock is well

* The Geology of North Wales, pp. 218, 221.

marked at parts (to the N.W. and the N.E.) by light- and dark-grey lines bending around pinkish crystals, and the rock, under the microscope, is seen to be much broken and silicified. Southwards the mass is compact and uniform; it shows at one place curvitabular jointing, similar to that figured by Professor Bonney from the basalt of La Prudelle *.

II. Some Petrological Characters of the Rocks.

The general character of the ground-mass has been indicated as fluidal and sometimes slaggy, with a finer or coarser devitrification. The distinct crystals are, many of them, alteration-products, such as forms of viridite or of chlorite, sometimes vermicular or spherulitic. Leucoxene is found, often with cuneiform magnetite within, and, in one rock, some apatite. Epidote is not uncommon, and, in several slides, is connected with aggregations of dark grains, which, although obscure, I believe to be themselves mainly epidote, either skeleton-crystals, or formed as pseudomorphs, possibly after augite. The spaces between the grains cross rectangularly, as might happen from a corrosion of that mineral. There is some free quartz, but the felspars form the chief of the porphyritic crystals. A few of these exhibit under polarization deep purple and red colours; some are kaolinized, some are clear, possibly a result of pseudomorphism; and others have undergone replacements, which I will discuss later.

The normal perlitic structure of glassy rocks is well shown †. Sometimes it is marked by viridite or a ferruginous deposit; and in slides from some noduliferous localities, fibrous chalcedony stretches across the cracks and fills them up, resembling in miniature the chalcedonic bands in the crust of many agate nodules.

Spherulites showing the black cross occur, sometimes isolated and rounded ‡. Some have viridite or a ferruginous deposit aggregated towards the centre. Others are clear and homogeneous, and look as if silicified; these are most marked where chalcedony has been deposited in perlitic cracks. They often form the whole ground-mass, "interlocking with irregular outlines," as described by Professor Bonney §, and doubtless indicate, as he suggests, some secondary change. They are similar to the spherulites ("hérissées d'aspérités") developed in glass by Daubrée's experiments ‖. In some slides the spherulites are not without relation to perlitic cracks, which may encircle them, or may be directed towards the interior and be traceable again beyond the interruption. In one example the ground shows perlitic

* "On Columnar, Fissile, and Spheroidal Structure," Quart. Journ. Geol. Soc. vol. xxxii. 1876, p. 146, fig. 6.

† Compare Mr. Rutley, "Lavas of Glyder Fawr," Quart. Journ. Geol. Soc. 1879, vol. xxxv. p. 508. "Rocks from Beddgelert and Snowdon," Quart. Journ. Geol. Soc. 1881, vol. xxxvii. p. 403.

‡ 'British Petrography,' J. J. H. Teall, pl. 38.

§ Pres. Addr. Geol. Soc. 1885, p. 68.

‖ Géol. Expér. p. 170, fig. 45; see also a group in the Saulieu rock, Min. Micr., Fouqué and Lévy, pl. xii. fig. 1.

curves, and appears also minutely broken, like crackled china, with small spherulites within the finer network.

Other spherulites, unmarked by the black cross, and exhibiting radial fibres, are connected with various micrographic or dendritic formations. These are occasionally developed in relation to dark perlitic lines. Some groups form incipient spherulites within angular spaces. From others of the lines, microlithic tufts start, like sedge-plants along the water's edge, similar to the dendritic growth described in Arran rocks *. One slide, cut from the junction of a non-spherulitic with a spherulitic stratum, shows that the boundary has given rise to a continuous series of fibrous tufts, like those formed along the border of adherent layers of glass †.

Some of the micrographic structure in the Pen-y-chain slides has resulted from an alteration of felspar; of such development, Prof. Judd has given one illustration—and seems to promise further examples—from rocks of the Western Islands of Scotland ‡. In the Lleyn specimens the alterations may result in granular pseudomorphs; but these are related to examples, as in those described by Mr. R. D. Irving, in which the "corrosion or secondary quartz" forms "rows of graphic particles" along the cleavage-directions, or develops as "fine lines" §. One group of felspars has been thus metamorphosed (fig. 3). A square end of one crystal shows three

Fig. 3.—*Micrographic Structure modifying successive zones of a Porphyritic Felspar. From Pen-y-chain beach.* (Enlarged 40 diameters.)

distinct zones, the outermost of which presents a rather irregular fimbriate growth. The zone next within has finer striæ, which meet at the corners along diagonal lines, forming in miniature a

* "On Rock Structures in Arran," Prof. Bonney, Geol. Mag. Nov. 1877, p. 508.

† Pres. Addr. Geol. Soc., Prof. Bonney, 1885, p. 65.

‡ Quart. Journ. Geol. Soc. 1886, p. 73, pl. vii. fig. 8.

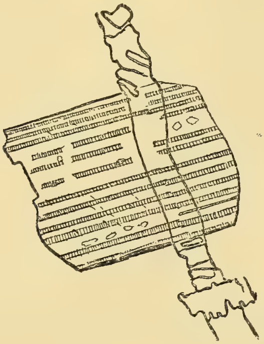
§ U. S. Geol. Surv. Copper-bearing Rocks of L. Superior, R. D. Irving, p. 113, pl. xiv. figs. 1, 2, pl. xv. fig. 4. See also Min. Micr. pl. ix., pl. x. fig. 2, pl. xi. fig. 1. Brit. Petrogr. Micro-pegmatite in pl. xxxv. fig. 2.

model of the devitrified sheet of glass described by Professor Bonney *, and showing similarly a shadowy transverse banding. A felspar in another slide includes a roughly spherulitic arrangement of micrographic growth, somewhat similar to the aggregation of fucoid-like pyroxene, illustrated by Mr. Allport †; but here at the centre of the radial group is a rounded quartz-grain.

The micrographic and spherulitic growth may thus develop within felspar crystals, or subsequently to the formation of perlitic lines. There may be, similarly, a somewhat late origin ‡ for the larger spherulites of nodular character. In them the radial fibres are linear and close, with a kind of pectinated arrangement, and traverse usually a mass of large secondary granules. These sometimes are elongated radially, as if they may have been constrained in their formation by an earlier fibrous structure, which, however, is not obliterated.

The micrographic structures seem not without relation to a silicification of the rocks, as has been suggested in connexion with some of the altered felspars. Other illustrations of such change occur in a rock from Careg-y-defaid, on an exposed surface of which are small superficial bosses; these Professor Bonney suggests to me are possibly a form of beekite. The microscope slide exhibits granular quartz, replacing porphyritic crystals, deposited along the even lines of flow, and within transverse veins, which interrupt without displacing the lamination, as if the rock had undergone a quiet continuous permeation by silica. One vein, about ·04 mm. broad, crosses a small felspar (fig. 4). With polarized light the

Fig. 4.—*Felspar Crystal traversed by a vein through which the plagioclase bands are continued. Silicified Felsite west of Careg-y-defaid.* (Enlarged 110 diameters.)



plagioclase structure is traceable in the crystal and across the vein, which, however, is still distinguishable, except at the positions of

* Pres. Addr. Geol. Soc. 1885, p. 66.
† Quart. Journ. Geol. Soc. vol. xxx. pl. xxxiv. fig. 28.
‡ See Prof. Bonney, Geol. Mag. dec. ii. vol. iv. 1877, p. 509.

maximum extinction. The twinning seems continuous, with only a very slight displacement along the middle of the vein, as if infiltration along this line had caused a pseudomorphism of the neighbouring crystalline structure, although it is not easy to understand the exact continuity of the plagioclase bands over the vein. Spherulites, in this and in other slides, seem as if great part of them had been corroded away, leaving scattered quadrants or sectors, with a suggestion of the concentric bands still traceable in the matrix beyond. Elsewhere, silicification has given rise to granular quartz, formed along an outer ring of a small spherulite transgressing its concentric zones. As to certain other structures, we may doubt whether to attribute them to an alteration of the rock-mass or to the infilling of cavities; although indubitable amygdaloids of quartz are present in many slides. In the rock, where radial tufts are developed along an adjacent stratum, brownish spherulites appear ragged and possibly silicified at their exterior, rather like an example from Lea Rock *, in which, however, the spherulite rays show less definite crystalline forms. The specimen from Pen-y-chain beach has long lath-shaped sections of faded crystals, penetrating the spherulites, and imbedded in the interspaces; but they are masked, in polarized light, by a clear granular mosaic of secondary formation. These crystals may project with simple terminations, or may cross in a kind of trigonal network. It is possible that they may be quartz crystals, but, as Professor Bonney pointed out to me, their general form would be unusual for that mineral, and they are most probably due to the replacement of some other mineral, possibly of a zeolite; and we may note how a dark deposit is aggregated along and around them, which proves to consist of very minute fluid-cavities containing bubbles. These might well have originated during the process of the pseudomorphic formation, by the consequent loss of water from the zeolite. The arrangement of the crystals, both here and similarly within lenticular spaces in the neighbouring layer, is suggestive of cavities, in which the first-formed structures grew freely, and were afterwards almost obliterated by a complete infilling of quartz. Among the Allport Collection in the British Museum (which, by the kind permission of the authorities of the Department, I was allowed to examine) is a slide from an altered pitchstone of Lawrence Hill, containing somewhat similar structures, which seem less dubious representatives of vesicles †. The specimen from the Lleyn is, however, so much modified, that we cannot be certain under what circumstances the secondary structure was produced; and the interspaces occasionally enclose what seem to be altered felspars, pierced by the lath-shaped crystals. Thus these formations must perhaps be left as doubtful pseud-amygdals; but they would still be an

* I was fortunately able to visit these rocks, and to receive some help in comparing their structures from Professor Bonney, during the Shropshire excursion of the class from University College.

† I am very much indebted to Mr. T. Davies, F.G.S., of the Mineralogical Department of the British Museum, for his kindness in allowing me to examine many slides and rock specimens in the petrological collection, which materially helped in illustrating these and other doubtful structures.

evidence of the process of silicification, which is illustrated in all the quartz-filled vesicles, and in changes superinduced in the matrix of the rocks.

III. Nodular Structures.

In the Survey Memoir the occurrence of these structures is noted *, but no details are given of their various forms.

1. *Perlitic Spheroids and Concentric Structures in Nodules.*—Certain of the nodules appear to be the result of simple contraction †, since they are lithologically similar to the rock which includes them; in fact, the boundary may be developed only on a weathered surface. In a slide from one example there is no difference in the closely spherulitic ground-mass of nodule and of rock, except a slightly darker staining in the neighbourhood of the boundary-crack.

Some of the masses found towards the east of Careg-y-defaid seem to be due to flow-brecciation; they are subangular, varying from about one inch to three feet across, and appear firmer and more silicified than the somewhat schistose matrix. Many of them are slightly elongated in the direction of the lamination, and are marked by a parallel fissuring, along which the ground-mass often penetrates into the nodules.

One of these brecciated masses, roughly rhomboidal in shape and rather larger (about six feet by three and a half feet), is full of half-inch spheroids, which exhibit sintery-looking concentric shells, recalling the description given by Zirkel of spherulites thus weathering ‡. Microscope sections show a kind of granular micrographic growth, with a partial attempt at a radial arrangement, the concentric hollows apparently developing within the less fibrous zones. If an external part of the lava had been broken up in the flow it would probably be vesicular; and it is conceivable that, under the altered conditions, vapours which were contained might expand to form the irregular concentric hollows, somewhat in the way described by von Richthofen §. We might suppose, however, from the partial and discontinuous spherulitic structure which borders the internal cavity and the exterior boundary, that the radial growth was possibly connected in its origin with contraction towards a centre, and that planes of weak cohesion might have thus arisen, as Professor Bonney suggested in explanation of the spherulitic felsite of Arran ||. The quickly-cooled and probably partially-cooled mass, broken up and carried along by the renewed flow of the lava, would be doubtless subject to more than one series of contractions, and the

* Geology of North Wales, p. 220.

† As in examples described by Professor Bonney, Quart. Journ. Geol. Soc. 1882, vol. xxxviii. p. 295; *cf.* M. A. de Lapparent, Bull. de Soc. Géol. de Fr. 1884, 3e sér. t. xii. p. 287, on Jersey nodules.

‡ U. S. Explor. of the 40th Parallel, Micr. Petr. p. 212.

§ Jahrb. der. k.-k. geol. Reichs. 1860, p. 181.

|| "Pitchstones and Felsites of Arran," Geol. Mag. 1877, dec. 2, vol. iv. p. 510. In specimens of the spherulitic felsite which Professor Bonney kindly showed to me the exfoliating layers with their "white dust" had an appearance not unlike in miniature that of the concentric shells described above.

conditions might thus be somewhat analogous to the secondary heating-up of the Arran felsite.

Near the point at Careg-y-defaid certain brownish nodules, from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch or less in diameter, occur in a compact greyish rock. The microscope shows the matrix to be devitrified and perlitic, and the nodules prove to be spherulitic; thus we have here another example, to add to those enumerated by Mr. Cole, of 'pyromerides' due to alteration of originally glassy rocks *. Around or towards the exterior is generally an irregular and often incomplete ring of quartz, and spherulitic tufts are best defined where rooted in the outer granules, or, in one example, where starting from a porphyritic crystal. Whether the quartz marks what was originally an irregular vesicle, or a space primarily due to contraction, the deposit seems to have further extended by a kind of replacement; for lines of minute enclosures run into it without interruption and continue from grain to grain.

Specimens of Jersey nodules †, for which I am indebted to the kindness of Professor Bonney ‡, exhibit the thin and numerous chalcedonic threads which are mentioned by de Lapparent as occurring between successive layers §. They are often crenated, and roughly concentric with an outer somewhat mamillated surface. It is difficult to decide upon the cause or causes of this tendency to concentric rings. If in an early stage gas was evolved in these spherulites, after they had begun to form, it would be likely to take possession of any spaces already existing, possibly filling and enlarging cracks formed in some contraction of the spherulite before it had "set." In the cavities thus originated, quartz might crystallize out, mostly supplied from the adjacent zones; these are now dark and decomposed, and are generally more irregular at their outer boundary. The definition of the quartzose arcs is prominently exhibited, on the cut surface of several specimens, by a capillary efflorescence, which developed in the course of a few days from the intermediate fibrous zones. The minute hair-like crystals consist, apparently, of magnesium sulphate (epsomite), probably due to a deposit from sea-water within the more weathered part of the spherulite. One specimen, which has exhibited none of this efflorescence, proves to be clearer and less decomposed, more markedly spherulitic, and nearly free from the concentric chalcedonic rings.

Some connexion of spherulites with a kind of perlitic contraction, possibly of later date, seems indicated in certain slides, especially in a Lea-rock and a Boulay-Bay example, where a sharply-defined narrow quartzose vein bounds part of the spherulite, which is

* Geol. Mag. July 1887, p. 303.

† See "Rhyolites of Bouley Bay," by Mr. T. Davies, 'Min. Mag.' 1879, vol. iii. p. 118.

‡ I have also had the advantage of studying some additional illustrations from Jersey, kindly lent by Mr. Percy F. Kendall, of Owens College, Manchester.

§ Bull. Soc. Géol. de Fr. 1884, 3e sér. t. xii. p. 284. Compare the "concentric zones caused by successive growths" within Gargalong pyromerides described by M. Lévy, Bull. Soc. Géol. de Fr. 1875, 3e sér. t. iii. p. 223.

traversed in various directions, often radially, by other siliceous veins.

2. *Origin of the Agate-nodules.*—The crust of the true agate-nodules is spherulitic, sometimes with concentric zones, which may be marked by an infilling of secondary chalcedony. Occasionally traces of the rock-lamination and porphyritic crystals are contained in it, proving here, as by similar evidence and by chemical analysis has been shown elsewhere, that the crust is an altered portion of the rock-mass. This outer part is generally lined with small granular quartz, or with mamillated fibrous chalcedony, which sometimes forms beautiful spherulites, and may fill up the interior of the nodule; in other examples the heart of the cavity is occupied by an aggregation of large quartz grains, or it may be hollow, with crystals projecting inwards. Cavities, empty or filled in, which, I presume, might be similar to the interior of these nodules, have been described, as resulting from decomposition of the central part of a spherulite, or as originating from vesicles caused by disengagement of gases *.

Among the difficulties of deriving the nodules from original spherulites by a process of hollowing-out are the occasional appearance of neighbouring felspars not much silicified, and the occurrence, in connexion with the central cavity, of sharply defined chalcedonic veins, which traverse the spherulitic crust. These veins sometimes appear to be subsequent formations, but the history in certain of the examples is clearly shown. Chalcedonic deposit lined the central cavity and filled up concentric rings in the crust. After a pause, deposition recommenced, and the heart of the cavity, which had remained vacant, became completely filled up. The veins therefore, in this case at least, cannot be connected with any action of decomposition, since they can be traced, through a thick envelope of chalcedonic deposit, to the small cavity which they have evidently supplied. By inference, we should therefore incline to consider similar veins elsewhere as feeders to other cavities within nodules. The fissures are usually part of a general system of brecciation, which has affected the spherulite, in many examples, either radially or along concentric surfaces. Owing to the existence of radial cracks, a sector may be displaced, so as to project beyond the surface of the rest of the sphere; and such sectors may appear as if they had contracted away from one another at the heart of the spherulite. The stellate outline of the central cavity within some agate-nodules may very probably be correlated (as Professor Bonney pointed out to me) with this tendency to radial cracking and tearing at the centre.

Further, while, as Mr. Cole suggests, the centre of the spherulite might be a less resistant part †, yet the exterior would seem to be as much—or far more—exposed. The ends of the fibres, in some instances, like the terminations of cleavage-planes in some crystals,

* See "Nature and Origin of Lithophysæ," J. P. Iddings, Amer. Journ. of Sci. vol. xxxiii. Jan. 1887; and Mr. Cole, Quart. Journ. Geol. Soc 1885, vol. xli. p. 162; and references given in these papers.

† "On Hollow Spherulites," G. A. J. Cole, Quart. Journ. Geol. Soc. 1885, vol. xli. p. 166.

would be liable, I should have thought, to yield to corrosion (as in small examples which I have mentioned), if such extensive decomposition had acted at the heart of the nodules.

It seems also as if, in any differential action upon the spherulite and its environment, the matrix is far more readily altered, and thus it so often acquires a schistose character, as if squeezed between the more compact nodules. Professor Bonney tells me that at Boulay Bay the pyromerides are often only faintly traceable on a fresh surface of the rock, but are well developed after weathering. A microscope slide from one specimen shows a very clear granular aggregation deposited in the perlitic ground-mass, while alteration of the spherulite seems much less marked. In one of the Lea-rock slides greenish oblong microliths, with a rectilinear arrangement, seem to mark an original structure, sealed up in the firm spherulite, while a contorted fluidal development has been set up in the less resisting matrix, which thus seems to flow around the imbedded spheres. The minute black microliths, like knobbed sticks, which are found within certain spherulites, and not within the surrounding matrix (as, for example, in some Boulay-Bay specimens), may perhaps be similarly explained, since their orientation is generally uninfluenced by the radial growth. Again, as I have described, spherulites have become subsequently fissured, as if they were less plastic than the matrix. Sometimes a continuation of the rock-mass seems to extend around a displaced fragment, as if, after the spherulite had begun to form, the glassy matrix was still in a somewhat viscous condition, and able to penetrate into cracks of the nodules *.

Spherulites can be found occasionally not complete, and some of these might perhaps be compared with the arrangement of material found in napoleonite, or in the spheroids described by Dr. Hatch †. It may be, however, that in some cases the development, in accordance with the principle suggested by Professor Bonney ‡, started from the exterior, but ceased before it had advanced far towards the centre, so that a spherulitic rind would be formed. A breach of continuity from the internal "residuum" might result, and the distinction of the two parts might be further accentuated by granular devitrification of the substance within. Weiss speaks of a greenish mass (similar, except in colour, to the matrix) contained within a fibrous crust §; and in a specimen from Pen-y-chain a darkened part, bounded by spherulitic arcs, is evidently a portion of the ground-mass. In the rock the perlitic cracks are mainly chalcedonized; but within the enclosed fragment they contain a greenish deposit, which gives it the darkened colour, and thus heightens the contrast with the surrounding border. Thus, in these incomplete nodules, a spherulitic crust encloses a central mass, which certainly could not here be a decomposition-product.

* Compare Amer. Journ. of Sci. vol. xxxiii. p. 42, Mr. Iddings, 1887.
† Quart. Journ. Geol. Soc. vol. xliv. p. 557, Aug. 1888.
‡ Geol. Mag. dec. 2, vol. iv. 1877, p. 510.
§ "Thur. Wald. Porph.," Zeitschr. d. d. geol. Gesell. 1877, Bd. xxix. p. 422.

Some intermingling in structure of the outer crust and of the quartz-deposit within seems traceable in a few nodules; but if the present condition of the spherulites had resulted from gradual change and concentration of silica *, or other slow alteration, we should expect such gradations to be much more marked and general. In the large number of examples the agate contained would usually be considered to have been formed by the filling of a cavity already existing as a cavity, and the transitional zone, traceable only when highly magnified, does not seem more than might arise in the process of infilling and siliceous alteration. Such modification would be facilitated if there was originally a vesicular nucleus, to act, as Prof. Judd has said, as a "laboratory of synthetic mineralogy" †. In some cases the cavity may have had a frothy pumiceous substance around or within it, the disorganization of which may have caused the chalcedonic deposit to be, at places, less clean and clear.

3. *Examples of Agate-nodules.*—Some masses of flow-brecciation at Careg-y-defaid, near those already mentioned, contain small rounded nodules, filled with chalcedony and bounded by a thin crust. Near by are larger nodules in a somewhat trapezoidal space on the beach, about ten feet by fifteen feet, which has the appearance of a conglomerate, or of a surface paved with close-set whitish-looking pebbles. The ground-mass, as in the surrounding rock, is schistose, with a "glistening pale green mineral," like the structure described by Professor Bonney from near Conway Falls ‡, and a firm band crossing the tract has slickensided surfaces; so that the area may have been displaced and modified by crushing. The nodules, too (the "agate-like nodules," I suppose, of the Survey memoir §), may owe their generally ellipsoidal shape and parallel arrangement to the action of pressure. A longitudinal section shows, in one case, a squeezed-looking X-shaped interior, and in others, as in the ammonite-like lithophysæ of von Richthofen ||, three or more irregular chambers superimposed (fig. 5), as if vesicles of adjacent layers had been included in one nodule. The cavities are filled with chalcedony; the crust contains porphyritic crystals, and its spherulitic fibres traverse, in the microscope slide, curious quartzose spheres, which are probably incipient segregatory structures.

Turning to Pen-y-chain, we find agate-nodules at four or five localities ¶. They are thickly developed on the east coast, along both sides of a small cleft, which seems to mark a fault. The overlying beds are finely laminated; the ground-mass has a perlitic structure beautifully chalcedonized, and is crowded with clear spherulites exhibiting the black cross. Large nodules, sometimes

* J. Szabó, Jahrb. k.-k. geol. Reichs. 1866, p. 89.

† "Tertiary Gabbros," Quart. Journ. Geol. Soc. 1886, vol. xlii. p. 83.

‡ Quart. Journ. Geol. Soc. 1882, vol. xxxviii. p. 290.

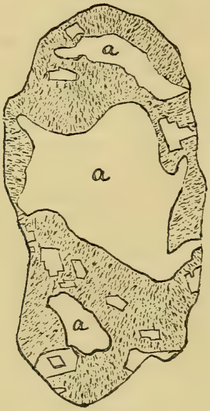
§ Geology of North Wales, p. 220.

|| Jahrb. k.-k. geol. Reichs. 1860, p. 181.

¶ Among the specimens which Mr. T. Davies kindly allowed me to examine was a slide much resembling the Pen-y-chain nodules. This specimen was from the Cleeve-Church boulder, which had been noted by Mr Davies, and has been suggested as probably Welsh in its origin. Min. Mag. 1879, p. 119.

5 inches or more in diameter, are scattered through the rock. The chalcedony, which fills the interior, often shows a platy structure parallel to the rock-lamination. The nodules are rounded, but are furnished with curious protuberant ridges, generally a complete equatorial and a partial meridional one, and occasionally others, which unite with some of the larger. The ridges are sometimes rather

Fig. 5.—*Longitudinal Section of Nodule from east of Careg-y-defaid.* (Nat. size.)



It contains three chambers filled with chalcedony (a). The crust is spherulitic, with porphyritic felspars, of which two are apparently clear and silicified, the others nearly opaque.

wavy. I thought I could trace them in one or two cases to the continuation of bedding- or joint-planes, and the internal cavity often extends to them. The most regular of the nodules reminded me, in external form, of that which von Richthofen figures as the usual type of lithophysæ *, only without the internal lamellæ. The radialized crust, here as elsewhere, is influenced by the internal cavity, and follows the stellar points of the interior, so as to form the outer skin of the ridges (fig. 6). The interior has the appearance of a possible vesicle, irregular in shape, often with convex sides and projecting angles. Where a cavity can be distinguished within the pyromerides of Jersey, it may be similar in form, and is often filled with chalcedony. At one part of the Pen-y-chain nodule, between the siliceous interior and the spherulitic crust, a small mass intervenes, consisting of minute scale-like globulites, scattered through shadowy chalcedonic granules. If this is due to the alteration of part of the rock-mass, as seems probable, it would negative here the theory of an originally complete spherulite. The radial fibres seem posterior to certain largish spherulites within the crust, which also contains others, much smaller and rudimentary,

* Jahrb. der k. k. geol. Reichs. 1860, p. 181.

marking the continuation of the rock-laminæ. As has been noticed in other cases, the lamination appears interrupted by the interior of the nodules * ; a breaking of the laminæ across vesicles is, however, by no means an unfamiliar circumstance in vesicular pumice.

Fig. 6.—*Section of Nodule with protuberant ridges ; from near rift along East coast of Pen-y-chain.* (Nat. size.)

The crust of the nodule shows concentric banding, and, when magnified, radial structure, as well as faint traces of the continuation of rock-laminæ (not shown in diagram). It contains porphyritic felspars much decomposed and chalcedonized.

a. (?) Portion of altered matrix, not spherulitic.

The chalcedonic deposit within consists of:—

b. Layer of fibrous chalcedony.
c. Chalcedony in mamillated or spherulitic masses, meeting along polygonal boundaries.

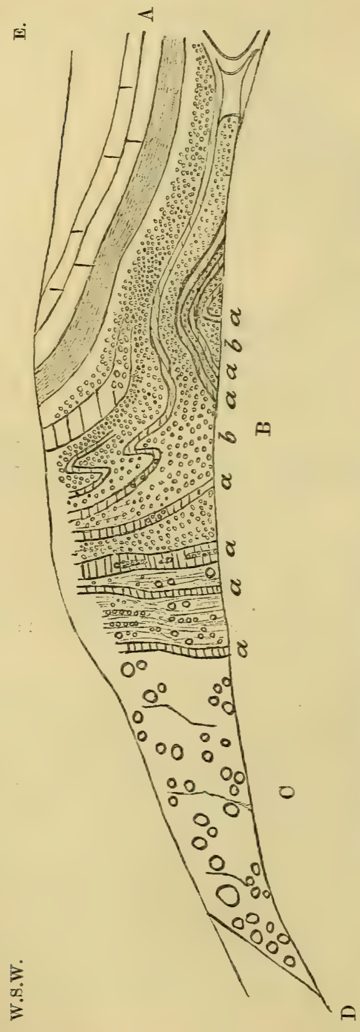
In a baylet a short distance northward of this small rift agate nodules are found, developed along certain beds (fig. 7). In the northern cliff the specimens are small, from half an inch to one inch across, and are crowded through a finely laminated matrix. The beds are crumpled into an S-shape, and become approximately vertical, marking probably the position of a fault. Westward, at the head of the recess, the nodules are larger, two or three inches across. They are sparsely developed in certain firmer layers, in one of which I found an aggregated spherulitic hemisphere (of about one inch radius) apparently without a central cavity; but the transitions between solid spherulites and those with unfilled hollow centres quoted from other localities † seem to be not common in the Lleyn.

* Mr. Cole, Quart. Journ. Geol. Soc. vol. xlii. p. 188. Mr. Iddings, Amer. Journ. of Sci. vol. xxxiii. p. 36.

† The "normal" and "abnormal" globules of Delesse. Mém. Soc. Géol. de Fr. 2e sér. t. iv. p. 300 ; and Bull. Soc. Géol. de Fr. 2e sér. t. ix. p. 432 ; (Thur. Wald.) Zeitschr. d. d. geol. Gesell. 1877, Bd. xxix. p. 420; (Jersey) Bull. Soc. Géol. de Fr. 3e sér. t. xii. p. 287 ; (Hungary) Jahrb. k.-k. geol. Reichs. 1866, p. 90.

One of the stronger layers proves, on microscopic examination, to be honeycombed with irregular vesicles, like a piece of trachyte. The firmness of the band is due to the hollows being filled up with quartz and the rock-mass silicified. This layer may represent the

Fig. 7.—Cliff of Baylet, Pen-y-chain, to show beds with Agate-nodules.



A. Finely granular compact layers without nodules.
B. { *a*. Firm bands, silicified, originally vesicular, containing nodules sparsely.
   { *b*. Layers crowded with small nodules.
C. Cliff, with much larger, more scattered nodules.
D. Post-tertiary deposit.

The beds show a fine lamination, but the crowded nodules and the crushing obscure and interrupt its appearance. Occasional bands, which are firmer, can be traced without difficulty. Joint planes, nearly horizontal, cross the cliff, and are especially distinct in these firmer bands (B, *a*) and over the western part (C).

outer more vesicular part of the original lava-flow; the deeper mass, cooling and contracting, gave rise to perlitic structures, and the vapours contained may have been emitted and collected in larger vesicles, which occur at the heart of agate-nodules.

Near the south-east corner of the Pen-y-chain promontory agate-nodules occur in beds which are much contorted, and are apparently slaggy lava-flows. Some of the nodules are large, while others, more crowded together, vary only from about $\frac{1}{4}$ inch to $\frac{1}{2}$ inch across. Close by, a rock-mass occurs, thickly set with small, almond-shaped, white quartz-nodules, usually $\frac{1}{4}$ inch or smaller, sometimes a hollow shell lined with pyramidal quartz—white or clear golden. These nodules appear, under the microscope, sharply limited (fig. 8),

Fig. 8.—*Diagram of Amygdaloids from old lava-flow at south-east of Pen-y-Chain.* (Enlarged 16 diameters.)

The amygdaloids are filled mainly with crystalline quartz. The outer grains are small; those of the interior are larger and clearer. In one example the cavity is partially empty (*a*). The devitrified ground-mass contains remains of porphyritic felspars (*b*).

although some of the quartz-grains transgress the boundary. Radial striæ of small enclosures may occur towards the exterior, and one example has minute microliths ranged approximately along straight lines in two directions, which cross at a high angle. The opinion might perhaps be advanced that the rounded nodules are a variety of pseud-amygdals, since adjacent structures have a radialized

crust; but this is thin compared with the quartz-filled interior, and may represent the early development rather than the vanishing traces of large spherulites (fig. 9). Crystals of felspar occur close

Fig. 9.—*One half of a Siliceous Amygdaloid, with a narrow spherulitic border. From old lava-flow at south-east of Pen-y-chain.* (Enlarged 8 diameters.)

This specimen is from a rock which contains the amygdaloids of fig. 8.

to the nodules, being actually sometimes in contact with them; some are kaolinized, others exhibit plagioclase twinning, but in none is there a replacement by quartz-granules. The nodules are elongated, and in more than one instance they bend around the angle of a porphyritic crystal, at a little distance from it, just as would often occur in the formation of a vesicle. Thus they seem to be amygdaloidal, and in that case we should be justified in concluding that similar cavities once existed in the neighbouring beds, around which a spherulitic growth arose; according to Lagorio it would be especially induced where gases and vapours passed through the rock*.

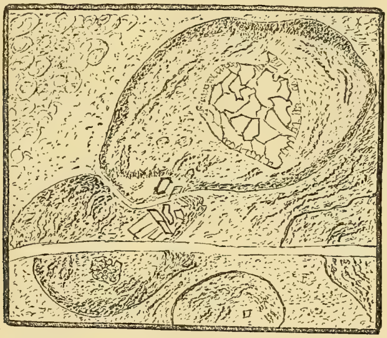
The above interpretation seems corroborated by some small pyromerides from Jersey, in which the interior has all the appearance of similar oval-shaped amygdaloids. A slide cut from another rock at Boulay Bay exhibits a contorted fluidal structure, with apparently rounded quartz-filled vesicles, as if the rock was originally glassy and pumiceous. Small veinlets of fibrous chalcedony extend between the lines of flow or curve around the vesicles. An attempt at spherulitic growth seems to fringe the vesicles, the chalcedonic veins, and the surfaces of contorted fluidal masses. It had been suggested by Professor Bonney, from his observations in the field, that some pyromerides might possibly be connected in their development with a differentiation of material in the lava, such as gives rise to a fluidal structure.

We might compare with nodules produced as I have just sug-

* Min. Mittheil. Bd. viii. p. 421. Abstract in Min. Mag. 1887, vol. vii. p. 223.

gested those which have been defined by spheroidal cracks forming around gas-vesicles, as explained by Professor Bonney in felsites of North Wales *. I have, from near Pwllheli, one beach-specimen, apparently formed by a similar process. It is a devitrified rhyolite, with fluidal structure, somewhat chalcedonized, and has patches of perlitic formations with viridite deposit. The nodules in this specimen are half an inch or smaller, oval in shape, and contain quartz-filled vesicles (fig. 10). The quartz is traversed by lines of enclosures

Fig. 10.—*Nodules, not spherulitic, in a ground-mass, which shows at places Perlitic Cracks with Viridite deposit. From the beach towards Pen-y-Chain.* (Enlarged 3 diameters.)



The crust of the nodule has a fluidal structure, and is more opaque along an exterior zone. The interior is filled up with granular chalcedony; but in one example the nodule encloses porphyritic felspars.

with moving bubbles, and the lines pass from grain to grain, as in the example figured by Mr. Cole †. The lines are parallel to the longer diameter of the nodules, as would result if the enclosures had originated from the action of pressure, in the way described by Prof. Judd ‡. The edge of the nodule for a little way inwards is more opaque, but otherwise the crust is similar to the surrounding mass, and exhibits a fluidal lamination, like that described by Prof. Bonney in nodules from near Conway §. One of the spheroidal cracks seems to have formed partially around a group of broken porphyritic felspar, something like the crack around olivine described by Mr. Rutley ‖. A somewhat different explanation for these nodules was suggested to me as a possibility by Prof. Bonney—that fragments of the lava crust, enclosing vesicles, might have been

* Quart. Journ. Geol. Soc. 1882, vol. xxxviii. p. 295.
† *Ibid.* 1886, vol. xlii. p. 188.
‡ *Ibid.* 1885, vol. xli. p. 376.
§ *Ibid.* 1882, vol. xxxviii. p. 294.
‖ Proc. Roy. Soc. 1886, p. 437.

broken and moved along in a viscous state by a renewed flow of the rock, and thus caused to assume an oval form, with more or less lamination of the crust.

At Pen-y-chain I found *in situ* one illustration of spheroidal formation induced around a foreign centre, where the nucleus was a rounded agate-nodule, three inches across, with a thick crust and an interior filled with white quartz. Around this, cutting across the lamination of the perlitic and spherulitic rock, was a crack defining a sphere some 13 inches in diameter. The part within the crack was slightly darkened, but otherwise similar to the mass of the rock. Prof. Bonney describes, in a microscopic slide, a cracking similarly caused by a strain around spherulites in a devitrified glass *.

I might mention also, in connexion with these specimens, an example which I found some years ago in a road-heap near Dolgelly. The rock is a kind of diabase, and has a dark ground-mass, in which are imbedded grey, flinty-looking, oval-shaped nodules without radial structure. The matrix is a slaggy-looking mass with deposit of viridite, and contains small felspars of plagioclase form. The nodules are similar, except that viridite is absent from their devitrified ground-mass, although it occasionally spreads along cracks, or aggregates around what are apparently central cavities filled with quartz. Porphyritic felspars, both orthoclase and plagioclase, occur, generally normal in appearance; but one crystal seems to be replaced by quartz-grains. There is small epidote, occurring in connexion with dark opaque crystals.

Summary.

I. At both the headlands of Pen-y-chain and Careg-y-defaid the character of the rocks clearly negatives the theory of intrusion. They are old lava-flows, once glassy, now devitrified, and, at Pen-y-chain, with interbedded agglomeratic and ashy strata. The proportion of silica has probably undergone subsequent alteration, but the frequency of porphyritic plagioclase suggests that the rocks approach nearer to dacites than to rhyolites †. As to the stratigraphical position of the Pen-y-chain rocks, apart from any vague suggestion of lithological resemblance, the general dip and the indications of a succession near Llym gwyn seem to afford a tolerable certainty of the Bala age of these volcanic accumulations. The dip is towards the north or east of north, and the rocks therefore belong to the southern part of the synclinal in which the Bala beds of the Lleyn are arranged. As suggested in the Survey memoir ‡, this synclinal may be traced eastwards, and the ashy beds near Pwllheli may be taken to represent similar strata of Snowdon and Moel Hebog. In like manner we may probably correlate the Pen-y-chain rocks with felsites exposed in those mountains. The mass of felstone also near Pwllheli, examined either in the field or by the microscope, shows

* Pres. Addr. Geol. Soc. 1885, p. 64.
† *Cf.* Rosenbusch, 'Mikr. Phys. der massigen Gesteine,' ii. Abth. p. 418.
‡ Geol. of North Wales, p. 218.

lithologically a marked resemblance, and contains similar nodular structures.

II. By their texture the rocks must be classed as petrosiliceous, and they illustrate in a marked manner many structures which are probably due to secondary devitrification *. They break with sub-concboidal fracture ; slides from them exhibit various micrographic and dendritic growths, and the ground-mass may be formed of spherulites "interlocking with irregular outlines." Other spherulitic formation occurs on a large scale in the pyromerides and in the radial crust of agate-nodules. Felspar crystals may be modified by micrographic structure, and are sometimes silicified, and chalcedony or quartz is found filling veins, the interior of nodules, and the hollows of vesicular lavas. Thus the rocks exhibit much evidence of a silicification (and often of a radialization possibly connected with it †), and we may imagine that the lessening activity of the volcanoes manifested itself in the percolation of heated waters carrying silica in solution. Geysers may have been in eruption near this locality; and some of the Ordovician conditions of the Lleyn may have been similar to the Miocene activity of Schemnitz or to modern phenomena in Iceland. Possibly some of the marked perlitic and similar structures were originated, or intensified, during the secondary alternations of temperature in this Solfatara-stage of the district.

III. The nodular structures seem capable of being classed in the following groups:—

1. Contraction-spheroids or magnified perlitic structures.
2. Masses resulting from flow-brecciation.
3. Solid spherulites or pyromerides.
4. Agate-nodules, with an outer spherulitic crust.
5. Quartzose amygdaloids.
6. Spheroidal formations developed around a nucleus, such as an agate-nodule, a group of crystals, or an original vesicle of the lava.

The large spherulites, where their relations are evident, seem developed either along certain strata or within masses of flow-brecciation. Generally, neighbouring examples show some approximation to a uniformity in their size. They stand out by weathering of the mass, as is very noticeable in the Jersey rock, where Prof. Bonney stated that, so far as he could see, they were well defined only on an exposed surface, and were scarcely traceable on a fresh fracture. They appear also to be generally uninfluenced by the pressure which has modified the matrix in certain Welsh localities. Thus the spherulite seems to be the most durable part of the rock. The mass of the rock very commonly exhibits an originally vesicular character, resembling that of a modern trachyte. The matrix surrounding the nodular spherulites consists, for the most part, of what must have been a compact, laminated, glassy lava, now devitrified,

* Pres. Addr. Geol. Soc., Prof. Bonney, 1885, pp. 68, 69.
† Compare Delesse, Bull. Soc. Géol. de Fr. 1852, 2e sér. t. ix. p. 175.

generally perlitic and often spherulitic. The interior of the nodule is in many cases filled with chalcedony, and is not distinguishable in form from an original vesicle of the lava; it is sometimes rounded and amygdaloidal, often it is irregular and may be somewhat stellate.

As illustrating their mode of formation, the agate-nodules of the Lleyn are wanting in the freshness of those recently described by Mr. Iddings from Obsidian Cliff, although in these old and more obscure forms, notwithstanding their siliceous alteration, a connexion with vesicles seems to be indicated *. The evidence from them appears to support these considerations:—

(1) That spherulitic growth originated, on the principle described by Prof. Bonney, from a surface of discontinuity. This is illustrated by the radial tufts which have formed in one rock along the line of an adjacent stratum, and in others along perlitic cracks. Gas-filled vesicles might be specially liable to cause such change in the rock; and radial growth may have thus begun around cavities, such as those forming the amygdaloids of the south-east of the Pen-y-chain promontory.

(2) That possibly contraction may have acted (sometimes around vesicles) to produce weakened concentric surfaces, or to have induced incipient spherulitic growth †.

(3) The spherulitic formation sometimes paused and recommenced, giving rise to a concentric banding. Protuberant ridges may thus have been formed, where a communication was kept open into the cavity of the nodule. The renewed growth might be connected with recurrence of conditions of moderate heating, since spherulitic development has been induced artificially in glass, under temperatures sufficient to soften without fusing its substance ‡.

(4) Such changes, by heating or an alteration of pressure, might cause irregularity of vesicles already existing, or brecciation of the spherulitic nodules, possibly even giving rise to fresh evolution of gas, if the volcanic glass were of the hydrated character, which has been proved of many examples.

(5) Cavities in a rock permeated by siliceous infiltrations would be likely to give rise to some modification of the surrounding crust; and where this was already spherulitic, the next stage of alteration

* Am. Journ. of Sci. vol. xxxiii. p. 36. It is possible that some earlier stage, now masked, might bear out, for some of the examples, the dehydration theory proposed by Mr. Iddings, as in the isolated ridged nodules which I have described in an old obsidian cliff at Pen-y-chain.

† Geol. Mag. 1877, dec. 2, vol. iv. p. 510. It seemed worth considering whether in the formation of concentric surfaces there might have been a shrinking due to the passage from hydrated to anhydrous glass, in the course of crystallization, as indicated by Mr. Iddings; but in that case the concentric rings should accompany the more marked spherulitic or crystalline structure, which does not seem always in accordance with the facts. Unless we could suppose that the primary contraction was centripetal, causing incipient crystallization along an outer limit, and that the subsequent growth resulted in a drawing together of the crystalline elements towards the outer fibrous rim which had already "set."

‡ Pres. Addr. Geol. Soc., Prof. Bonney, 1885, pp. 65, 67.

might be to form the shadowy devitrification-granules, which sometimes coexist with the radial arrangement of fibres.

I have ventured to think that the formations here indicated may be of interest, as affording some additional illustrations of structures described in the various papers quoted. Throughout my attempt I have received from Prof. Bonney much continuous help, the value of which I need not specify. It has included advice and assistance in many difficulties, as well as the opportunity afforded me of examining rocks and rock-sections from various localities. Examples from Jersey were of special interest, and the gift of some of these specimens, which was made the more valuable by notes on the general character of the rocks, enabled me to compare their microscopic structure and to find in it some confirmatory evidence.

Discussion.

Mr. Cole remarked that some features connected with the spherulites appeared to bear out his views. A complete illustration of the phenomena of the Lleyn felsites is furnished by the Permian pitchstone of Zwickau.

In one of Miss Raisin's specimens a small film with beautiful spherulitic structure projected into the central quartz-mass, apparently pointing to the destruction of the central portion. In Mr. Iddings's specimens the cavity, when existent, is comparatively small, and the typical hollow spherulites of Wales cannot be explained even by comparison with lithophysæ.

Dr. Hicks believed that the hollows in the nodules had been subsequently filled in with secondary silica, but that the cavities, in the majority of cases, originally existed in the rock.

Prof. Bonney commented on the too close comparison between small things and great. He still remained sceptical as to Mr. Cole's explanation. The vesicles became more irregular in outline in the more acid rocks, and the proposed interpretation of sections might thus be erroneous. The Boulay Bay specimens seemed to show that the spherulites were the least decomposed part of the rock, and there was evidence that, in a non-spherulitic part of the mass, the cavities had existed from the first. He had not gathered from Mr. Iddings's description that either the spherulites or the cavities in the Yellowstone rocks were so small. These rocks were beautifully fresh, so that Mr. Cole's explanation could not be applied to them.

16. *On the* Occurrence *of* Palæolithic Flint Implements *in the* Neighbourhood *of* Ightham, Kent, *their* Distribution *and* Probable Age. By Joseph Prestwich, D.C.L., F.R.S., F.G.S., &c. (Read February 6, 1889.)

[Plates IX.–XI.]

It has hitherto, with a few disputed exceptions, been generally held that, in this country, palæolithic stone implements are confined to "river-drifts" and caves of the so-called Postglacial age, in which they occur buried at greater or less depths; and little search was made outside the drift-deposits, or the valleys to which such deposits are confined. It is true that a few specimens had been found at various heights on the hills, but they failed to attract much attention or to suggest any different explanation. In 1861 Dr. John Evans * found a large pointed implement on the surface of a ploughed field in the parish of Abbots Langley, and at a height of 160 feet above the Colne. Another smaller specimen was found in 1861 by Mr. W. Whitaker on the surface of the Chalk, one mile east of Horton Kirby, and about 200 feet above the Darent †. In 1869, in searching over a field near the edge of the Chalk-escarpment at Currie Farm, Halstead, Kent, in company with General Pitt-Rivers, Sir J. Lubbock, and myself, Dr. Evans picked up a rude ovoid specimen; but we did not succeed in finding any more. This spot is nearly 600 (not 500) feet above O.D. From time to time a few similar instances have been recorded; but they were either passed by as chance specimens, possibly dropped and lost, or were in some way supposed to be connected with the ordinary river-valley drifts ‡.

But the remarkable discoveries of palæolithic flint implements made during the last ten years by Mr. Benjamin Harrison, of Ightham, in the neighbourhood of that village, and lying on the surface of the ground, at all levels up to nearly 600 feet above the sea §, showed that the subject required further investigation. I was otherwise engaged when Mr. Harrison first called my attention to his discoveries; and though from year to year I have paid occasional visits with him to the different sites where he had found palæolithic implements, it was not until this last summer that I was able to complete my survey of the ground, and come to

* See his 'Ancient Stone Implements of Great Britain,' chapter xxiii.

† Mr. De Barri Crawshay, of Sevenoaks, has since found a rude ochreous scraper in a field by the side of the road on the top of the same hill, at 390 feet above O.D.

‡ Ancient Stone Implements, p. 531.

§ Since this paper was written, Mr. Harrison informs me that he found a palæolithic implement, very like the Currie-Wood specimen, on the summit of the chalk-escarpment above Wrotham, at a height of 750 ft. above O.D. I have not yet been able to visit the spot.

the conclusions which I now beg to bring before the Society. Although long acquainted with the ground generally, it was evident that this inquiry needed a more special study of the drift-beds and physiography of the district *. For this purpose I have visited with Mr. Harrison, who possesses an intimate knowledge of the ground, every locality where traces of drift and flint implements have been found †.

Mr. Harrison's attention was first directed to the subject about the year 1863, when he found on a heap of stones gathered off a field to the S.E. of Rose Wood, near Ightham, and at a height of 475 feet above O.D. and 300 above the valley, a large, massive, pointed, flint implement. He subsequently found a few others on the surface of adjacent fields, but did not begin a systematic search until 1879. Since then he has found within a radius of five miles around Ightham above 400 specimens. These were, with very few exceptions, all on the surface of the ground and at all levels, from a few feet above the present streams to nearly the summit of the highest hills; and he rightly collected not only the well-marked specimens but also the more obscure forms, amongst which are some that seem to belong to the earliest implements fashioned by primitive man in England.

Local Topography.—The topography of the district is somewhat exceptional. Ightham is situated on the Folkestone Beds of the Lower Greensand. One branch of the small stream ‡ which flows through it southward to the Wealden area rises at the foot of the Chalk Downs 1½ mile above the village, and the other turns round westward to springs on the slope of Oldbury Hill. On either side, and at a distance of about a mile from these head-waters of the 'Shode,' the surface-waters run—in one direction westward into a tributary valley of the Darent (a river flowing northward into the Thames), and in another direction eastward into the small stream which flows past Malling and Leybourne into the lower Medway (see fig. 1, p. 272). The watersheds which part the Shode from these other two streams consist of low ridges of Gault and Lower Chalk, rising only a few feet above the level of the upper waters of these streams. But as the Shode flows south through the range of the Lower Greensand, high hills rise boldly on either side, forming a deep and picturesque valley as far as the junction of the Shode with the broad Medway valley in the Wealden area, near Hadlow (see Map, Pl. IX.).

Sections of the Ightham Valley.—Section No. 1 is taken at a

* Mr. Topley gives a general account of the drift of the district in his 'Geology of the Weald' (Mem. Geol. Survey, 1875); but owing to the absence of open pits, and to the very small size of many of the patches, some of the drift-gravels are apt to escape notice unless observed by some one residing in the district, and who has the opportunity of working over the freshly ploughed fields, and taking advantage of every chance opening.

† His manuscript lists give the locality and height above sea-level of every specimen, and their general character and form.

‡ On the Ordnance Maps no name is attached to this stream. Mr. Harrison informs me that on Symondson's old map of Kent it is called the 'Shode,' but that it is known in the district at present by the name of the Busty or Buster.

Sections of the Shode Valley.

Fig. 1.—*Across the Head-waters and adjacent Watersheds.*
(*The North Downs in the distance.*)

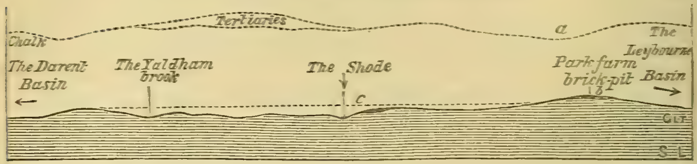


Fig. 2.—*From Oldbury Hill to Highlands Hill.*

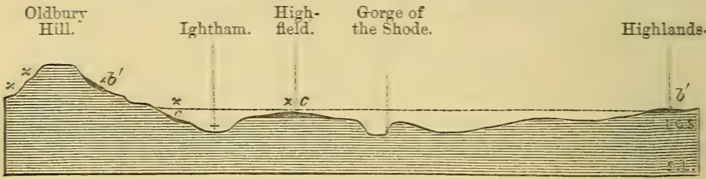


Fig. 3.—*From Ightham Common to Comp Wood.*

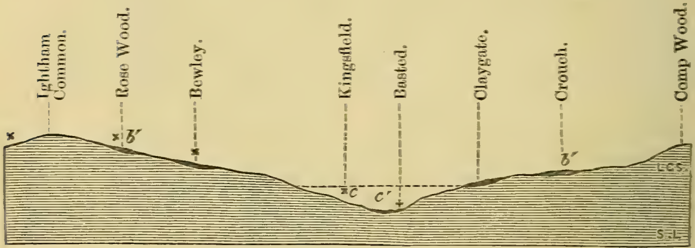
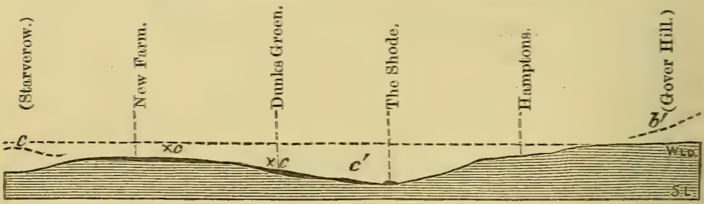


Fig. 4.—*From Shipborne to Hamptons.*



a. Traces of an old drift of worn and stained flints.........		(Preglacial ?)
b. Unstratified gravel of white flints *b′*. Hill-gravel	of uncertain age ...	(Glacial ?)
c. High-level Valley- or River-gravel .... *c′*. Low-level Valley- or River-gravel		Post-glacial.

×. Sites of Palæolithic Flint Implements.

----- Highest old river-level. S.L. Sea-level.

(Vertical scale $\frac{1}{2}$ inch = 100 feet. Horizontal scale 1 inch = $\frac{7}{8}$ mile.)

distance of about half a mile from the head of the main stream (the Shode). Nos. 2, 3, and 4 follow in succession in descending the valley at distances of from 1 to $1\frac{1}{2}$ mile apart. No. 4 is close to the junction of the old Shode with the old Medway valley. The height at which the Shode flowed at its earlier stage is regulated by the height of its watershed, and is marked by the horizontal broken lines. These are slightly too low in figs. 1 and 3, and too high in fig. 2.

This small stream is ten miles long from its source above Ightham to its junction with the Medway; but the old stream, when both rivers flowed at a higher level, was not more than six miles in length, with a breadth of channel seemingly of from $\frac{1}{2}$ to $1\frac{1}{2}$ mile; while that of the Medway, at Tunbridge, could scarcely have been less than five miles in width. Since that time the channel of the Medway has been lowered 220 feet or more, and that of the Shode in proportion; for the high-level (275 feet) river-drift of the Medway at Little Park * is three miles north of Tunbridge, and the nearest hills south of the Medway, which are high enough to have formed the southern shore of the old river, are at least five miles distant from this point (see fig. 4, p. 272).

The spring which forms the fountain-head of the Shode is thrown out by the Chalk Marl or Gault at the foot of the North Downs on Newhouse Farm, near Wrotham, at a height of 380 feet above ordnance datum, but after heavy rains it issues $\frac{1}{4}$ mile further north, at the higher level of 400 feet or more.

The lowest level of the watersheds which at present separate the Shode from the basins of the Darent and Leybourne is not more than about 320 feet above O.D.; but judging from a patch of older gravel at Park-Farm brick-pit, which there caps the Gault at a rather higher level, they may originally have been about 340 feet.

Consequently the Shode could not, since these hydrographical basins have assumed their present contours, have flowed at a higher level than about 340 feet; and this is the height to which its highest terraces must be limited in its upper reaches; while, allowing for the fall of the river, they might be from 50 to 60 feet less in the lower reaches. All those drifts which exceed these heights will therefore have to be assigned to causes other than those depending upon the *régime* of the existing streams, and to a date anterior to them.

The River-Drifts of the Shode.—These, as might be expected, are small in quantity and scattered very sparsely at a few levels. Their thickest spread is near Ightham. Above the village there are thin patches of gravel on the lower slope of Fane Hill and Bayshaw, near Oldbury, and at Coney Field on the opposite bank of the stream, at the level of from 300 to 330 feet, and apparently from 2 to 4 feet thick; but there are no pits now open to show the exact thickness †. These gravels consist essentially of white, angular and

* There is another outlier mentioned by Mr. Topley at Starvecrow, one mile to the south of this, and at the height of 253 feet, consisting, like that at Little Park, of subangular flints and chert, with Tertiary flint-pebbles and Wealden *débris*. (Geology of the Weald, p. 185.)

† Geology of the Weald, p. 185.

subangular flints, of Tertiary flint-pebbles, and of angular fragments of chert and ragstone from the Lower Greensand, the proportion of the former decreasing as we descend the valley, and that of the latter increasing; while a few miles down, at Dunks Green, Wealden *débris* appears.

The most important patch of this "river-drift" is a little above and east of Ightham, at a spot called Highfield. It there forms a bed of gravel about 8 feet thick and 320 feet above O.D., or of 60 feet above the Shode. Lower down there are terraces of scattered river-drift at Crowhurst, on the right bank of the stream, and on the left bank between Basted and Crouch, at about the same level of from 300 to 320 feet. Below this there is little river-drift to be met with until we reach Dunks Green and Shipborne, where, at a level of from 200 to 250 feet, is another thin, though better-marked, patch of gravel, from 2 to 3 feet thick; and at Broadfield, on the opposite side of the Shode, there are a few scattered flints and pebbles, which may carry the river-drift to a height of 270 feet, or of from 140 to 150 feet above the Shode. There is another small patch on the ridge between the Shode and the Mote stream (*c*, *c'*, figs. 2, 3, 4, p. 272).

In the small portion of the Darent basin with which we have to deal there are very few "river-drifts." There are traces of gravel below Stonepit and Fuller Street which may be referred to them; but the best-marked patch is on a lower level in the railway-cutting at Child's Bridge, near Seal. This latter only covers a few acres, is from 4 to 5 feet thick, ochreous, and roughly stratified. It is composed in greater part of Lower Greensand *débris* *, with very few flints and flint-pebbles. Some of the flints are pitted, and others stained brown and subangular.

In the basin of the Leybourne stream a bed, apparently of river-gravel, extends from below Offham Church at the level of 230 feet to West Malling, where its level at St. Leonard's Tower is from 180 to 200 feet above O.D. It consists of subangular flints, chert, and Tertiary pebbles in a sandy matrix. There are no pits to show its thickness. On the other side of the stream there is a slightly lower terrace (described by Mr. Topley) capping Leybourne Hill at a height of 153 feet above O.D., or of 75 feet above the stream, and traces of the same are visible at Larkfield Heath.

There are some lower-level gravels near Ryarsh, but without sections, and the old pit on this level, near Leybourne Church, is now closed. At the junction of this valley with that of the Medway there is, however, a large pit on a well-marked terrace about 60 feet above O.D., capped by an ochreous gravel composed of a mixed *débris* of subangular flints, weathered chert, and Tertiary flint-pebbles, with a considerable proportion of Wealden pebbles †.

Unfortunately there are neither river-shells nor Mammalian remains in any of the Shode gravels to certify to their character:

* Mr. Harrison reports one fragment of Oldbury stone; but this may have come from some of the hills west of Oldbury.

† See Topley's 'Geology of the Weald,' p. 174.

but this is not an uncommon feature of beds of this class*. In separating them therefore from the higher gravels, which extend at heights of about from 400 to 500 feet on the Lower Greensand range of hills, through which the Shode valley cuts, I have had to rely solely upon levels and physical features and characters.

Another source of difficulty arises from the circumstance that owing to the absence of sections which would show whether or not we are dealing with substantial beds of drift *in situ*, or whether the appearance of drift is merely due to the trail from higher-level drift-beds, it is uncertain whether some of the intermediate supposed drift-gravels, such as those near Crouch and below Bewley, together with others, may not belong to superficial *trail*.

The problem is further complicated by the fact that the Shode "river-drifts" are largely composed of materials derived from the older drifts, so that on lithological grounds alone they cannot well be distinguished.

The Higher Unclassed Gravels.—These I would divide into two or more groups. A lower one consisting of angular white flints, with very few Tertiary flint-pebbles, and little Lower-Greensand *débris*, imbedded in a local matrix, without stratification. Of this drift a small remnant caps the watershed at Park-Farm brick-pit, about 340 feet above O.D., resting on an uneven surface of Gault, and having an argillaceous matrix. No organic remains have been found in this gravel, which is of date anterior to the Shode valley.

Another group, consisting chiefly of flint-*débris* and occupying levels higher than this or than that to which the river-drifts reach, occurs in irregular mounds on the hills extending east and west on the south side of the Holmesdale valley †, and crossing the Shode valley at Ightham. One such patch caps the Folkestone Beds at Cop Hall, 420 feet above O.D., half a mile south of Ightham, and consists of angular white flints, with a little Lower-Greensand *débris* and a few Tertiary pebbles. With these I would correlate the mounds of gravel which, two to three miles east of Ightham, cap the same range of hills at a height of 388 feet at Gallows Point and Highlands, and form well-defined ridges commanding the surrounding country (fig. 2, p. 272). The drift is there composed chiefly of angular flints (some of large size), weathering very white, with worn subangular brown flints, some fragments of chert and grit, and a few Tertiary flint-pebbles; whereas, just to the south-east of Highlands and at a rather lower level, there is a large spread of ochreous flints, with little chert and a few blocks of Oldbury Stone. There is another abnormal bed of drift of uncertain age, composed almost entirely of chert fragments, with only a few angular white and subangular brown flints, and Tertiary flint-pebbles imbedded in a red clay, covering the rising ground between Comp and Offham

* No Mammalian remains had been discovered in any of the beds of old river-drift of the valley of the Darent previously to last summer, when some chance excavations brought a few remains of the Mammoth to light.

† The long valley which runs east and west at the foot of the Chalk-escarpment.

at a height of 340 feet. These latter, however, properly belong to the basin of the Leybourne valley.

Westward of Ightham there are traces of a similar drift at Oldbury Place, Kilnfield, and some other places round Oldbury Hill, which, like that on the slope of Sheet Hill, are so much mixed up with local *débris*, swept down from the heights of Oldbury Hill and Ightham Common above them *, that their distinctive character is obscured or lost. I shall have occasion at another time to show that these hill-gravels may be connected with other outliers described by Mr. Topley between Sevenoaks and Westerham.

In the Ightham Basin, a drift, higher than that of the river-valleys, and consisting of Lower-Greensand *débris* mixed with angular flint and Tertiary flint-pebbles, occurs on the left bank of the Shode, near Crouch, at the level of 356 feet, and again above Old Soar; while between the two, and at rather a higher level, there are pockets containing numerous Tertiary flint-pebbles. At the junction of the old Shode valley with that of the Medway, and high up the side of the hills, is another isolated patch of old drift, formed of Oldbury Stone, ochreous flints, white flints, and Tertiary pebbles, at the level of 350 feet on Gover Hill. This is the furthest point south to which this drift has been traced. On the opposite side of the valley, in a field west of Bewley Farm, a similar old drift of much-weathered chert, with very few flints and flint-pebbles, is met with near Bewley, at a height of 430 feet, and extending to 500 feet at Rose Wood. On the other side of the hill on the west, which, at the lowest pass, is 560 feet high, a sprinkling of angular and subangular flint-pebbles again occurs between Lower Bitchet and Stone Street, at the head of the dry valley that joins the Darent valley at Seal (figs. 3, 4, p. 272). Between Oldbury and Seal a similar drift, but with more chert and ragstone, is met with on the slope of the Greensand range, near Chart Farm, Stonepit Farm, and Fuller Street, at a height of from 360 to 420 feet or thereabouts †. On the hill west of Seal there is a similar drift (at 280–310 feet), but it is more flinty.

None of these high-drift gravels, for the discovery of all of which we are indebted to Mr. Harrison, can be referred to any existing system of drainage or river-action contingent upon the present configuration of the country, unless we except the patch at Seal, which may be connected with the Bitchet and Stone-Street Valley as an old tributary of the Darent; but the levels are difficult to coordinate.

We will now revert to the Ightham valley, and define the drift-beds which can be referred to the action of the Shode, as it flowed at successive levels during the excavation of its valley-channel. We may premise that, as a consequence of the low watersheds before named in the Holmsdale valley, the maximum level of the initial stream could not have exceeded by more than from 50 to

* I suspect that some of the other surface-drifts in other parts of the district may prove to be similarly masked.

† Some of this may, like the drift around Oldbury, be local *débris* or trail from the higher ground above.

60 feet that of the present stream at Ightham, though this may have been increased lower down the valley by the greater fall at its outlet, caused by the more rapid denudation of the Medway valley. We have therefore only to look to the drift-beds below the contour-level of 350 feet or thereabouts in the upper part of the valley, and of 300 feet or less in the lower part, where the valley is excavated to the depth of 140 feet (figs. 1–4, p. 272).

The tributary stream which passes by Ightham and rises on the slopes of Oldbury Hill must have at some time been one of considerable power; for its old bed above Ightham is, I am informed by Mr. Harrison, marked by a line of large blocks of the Oldbury Stone * which were exposed when the railway was being made. At Fane Hill, higher on the slope of Oldbury, the drift belongs in part to the Shode, as it does at Bayshaw, where it forms a bed of gravel 4 feet thick. Coney Field is covered by a white flint-gravel, which may also be of this age.

The slight sprinkling of drift on the low hills, bordering the other and main stream above Ightham, may possibly be a river-drift. Half a mile east of Ightham, at a spot called Highfield, just below the junction of the two main streams, there is a well-marked deposit of undoubted river-drift. It caps a hill rising from 50 to 60 feet above the Shode. The gravel is not worked; but a hole was dug, which showed it to be not less than 8 feet thick, roughly stratified, and composed approximately of:—

Subangular white flints (some of them pitted), together with a few others, much worn and deeply stained brown .... about	50 per cent.
Lower-Greensand *débris*, consisting of subangular ragstone, chert, grit, ironstone, and Oldbury Stone	45 „
Tertiary flint-pebbles..	5 „
	100 „

in an ochreous sand; no fossils were found.

In the valley a short distance below, and at a level of a few feet above the stream †, a well-marked bed of low-level gravel is exposed near the Mills at Basted. It is 6 feet thick, but is not worked, and consists chiefly of chert *débris*, with a number of blocks of Oldbury Stone, and a certain proportion of flints and flint-pebbles.

How much of the scattering of subangular flints, chert, and Tertiary pebbles at Claygate and the opposite Bewley slopes is to be assigned to a high-level river-drift, is, in the absence of sections, impossible to say. At Dunks Green, however, south of Plaxtol, and extending thence to New Farm, Shipborne, there is a well-defined

* The Oldbury Stone is a peculiar waxy chert, slightly translucent, of yellow, red, and grass-green colours, largely developed in the Folkestone Beds of the Lower Greensand at Oldbury Hill—a high hill (620 feet) west of Ightham, and at others adjacent. This chert, which is peculiar to this district, is easily recognized in the drift-beds. Mr. Trimmer found it on Dartford Heath, and I have found it in various parts of the Lower-Thames valley. It has been described by Prof. Bonney in Geol. Mag. dec. 3, vol. v. p. 297.

† The base of the valley, wherever exposed or cut through by the stream, shows a bed of gravel under a thin alluvial deposit.

spread of river-gravel from 2 to 4 feet thick, and at a level of 60–70 feet above the Shode, or 200–220 feet above the sea-level (fig. 4, p. 272). Here, in addition to the Chalk, Tertiary, and Lower-Greensand *débris*, the drift contains small flat Wealden pebbles, and is remarkable for the large number of blocks of Oldbury Stone—many of which are 2 cwt. or more in weight—which it contains. Roughly, the gravel is composed of:—

Subangular white flints, with others more worn and stained deep brown	40 per cent.
Lower Greensand *débris*, with blocks of Oldbury Stone	45 ,,
Tertiary flint-pebbles	10 ,,
Wealden pebbles	5 ? ,,

A low-level patch is recognizable about 20 feet above the stream at Hampton Mills, and a larger spread occurs a little north of Hadlow (at 110 feet), near its junction with the Medway-drift. The gravel, which is there intercalated with much sand, still shows a preponderating proportion of flints, flint-pebbles, and Oldbury Stone; whereas lower down the valley the Shode-drift becomes merged in that of the Medway; and at Goose Green, where the gravel is 10 feet thick, it is composed of:—

Much-worn chert and ragstone, of which Oldbury Stone contributes 5 per cent.	About 55 per cent.
Angular, white, and rolled stained flints, with a few Tertiary flint-pebbles	20 ,,
Wealden *débris*	25 ,,

and forms a low terrace 137 feet above O.D., or about 85 feet above the Medway.

The river-drift gravel in the valley of the Shode is in all probability derived in a large proportion indirectly from the older or hill-drifts, and not directly from the Chalk and Tertiaries. Nevertheless, although no stream now flows from the Chalk hills, at an early stage of the Shode there may have been contributory streams from the escarpment above Ightham; for on the top of the Chalk Downs, which rise above the head-waters of the Shode, there is a considerable outlier of Tertiary sands, shingle, and clay (fig. 1, p. 272), and a portion of the rain-water falling there, instead of passing at once into the Chalk, lodges in the Tertiary strata and escapes on the sides of the outlier. In ordinary seasons this water disappears on reaching the outside Chalk-surface, either by absorption or by means of the swallow-holes common in such areas *. But in times of excessive rains these channels of drainage prove insufficient, and the water forms torrential streams of limited extent, which follow the apparently narrow channels of extinct watercourses now filled up with the flints and pebbles carried down during former periods of great rainfall; and this *débris* is now on a few rare occasions broken up afresh and transferred to lower levels. Or else the water, sinking down through fissures and swallow-holes in the Chalk, so increases the volume of the under-

* The author, in Quart. Journ. Geol. Soc. vol. x. p. 222.

ground waters, that they burst out at unusually high levels on the lower slopes of the Chalk-escarpment on the line of other old watercourses now dry.

A remarkable instance of this occurred during the heavy rainfall of the 31st July, 1888. In this case an old farm-road had been carried up from the foot of the downs near St. Clere to Drain Farm on the top, a distance of $\frac{2}{3}$ mile. Along and under this road was what proved to be an old watercourse, filled with a mass of angular flints. The rush of water which escaped from the Chalk was so great that the lower part of the road for a distance of 230 yards was torn up, and a narrow rent formed along the whole of that distance from from 3 to 5 feet deep through this flint-rubble*. Cart-loads of the flints, some of which were of a large size, were carried down and thrown across the road (the old Pilgrim's Way) to the depth of from 2 to 3 feet, and on to the opposite field. We may suppose, therefore, that towards the close of the Glacial period, what with the melting of the snow and ice, and possibly a heavier rainfall, the slopes of the Chalk Downs were scored at places by watercourses such as this, and that ultimately, as the force of the waters decreased, these old channels became blocked up and levelled by the flints brought down from the higher ground. In this way the Shode, during its earlier stages, may have received some of the flint and Tertiary flint-pebble *débris* found in its drift-beds.

There are, however, other component parts of the Shode drift-gravels, for the origin of which we must look elsewhere. Amongst these are some large angular broken Chalk-flints, weathered white, and often pitted or pock-marked in a peculiar manner, and with the edges slightly worn. These differ materially in aspect from the bulk of the other flints, and are derived apparently from an old unstratified gravel that frequently overlies the Gault in the Vale of Holmesdale, and of which a patch before mentioned caps the watershed at Park-Farm brick-kiln. I have reason to think that this gravel may be of Glacial-period origin; but this can be shown better in places in the Darent basin, which I hope to describe on a future occasion.

There is also a marked variety of subangular flints of a very different character, not unfrequent in all the drift-gravels of the district. These flints are easily recognized by the extreme wear of their edges due to long abrasion before they became imbedded in their present positions. They are also deeply and uniformly stained a warm brown colour, in marked contrast with their surroundings. For the first source of these stained flints it is difficult to account; they have evidently been derived originally from some very old drift, which I have not yet found *in situ*. They may be traced from the Shode river-drift to the older hill-drifts of Cop Hall and Highlands, and from these again to the Chalk-plateau, where they predominate in places on the Red Clay with flints; but this does not carry them quite home.

* Equally remarkable, I am informed by Mr. Harrison, was the rush of water down the dry Chalk valley on the other or north side of Drain Farm. It re-excavated old channels, swept down hedges, and spread over fields. At one place a hole was left large enough to hold a waggon.

Brick-earth occurs in small quantities and at various levels. Mr. Topley has described a local mass of it on East Malling Heath, at an elevation of 290 ft.* It occurs also just below the Gault-pit on Park Farm at 340 ft., at Crown Point under Oldbury Hill at 490 ft., on the line of railway just below Fane Hill at 300 ft., and again at Seal Chart Common, at a height of about 520 ft. It is possible that some of these beds may be, like the gravel-drifts, reconstructed from the earlier deposits.

Palæolithic Flint Implements.—It is on the surface of the land at all levels up to 600 ft., and associated generally with some of the above-mentioned drifts, that these memorials of early Man are spread. It requires, however, long and patient search to find them, and Mr. Harrison's collection is the result of many years' search at intervals of leisure. Of all these specimens he has kept a full record, noting the height above the sea-level, and giving a slight sketch of each implement. They appear to have been found at 42 different localities. The following is the list of these he has drawn up for me, arranged alphabetically, with the height above sea-level, and the number of implements found at each place †:—

Localities (within 5 miles of Ightham).	Number of recorded specimens.	Height above the sea-level.
		feet.
Ash (including those found by Mr. De B. Crawshay)	30?	500
Bower Lane, near Eynsford	12	520
Bitchet and Stone Street	15	530
Bewley Valley (Parsons-brooms and Warren Plantation)	56	400 to 435
Buckwell (and Clay-pit field), S. of Chart Farm	3	364 to 384
Bayshaw and Robsacks, N. of Ightham	4	303 to 320
Borough Green	1	300
Basted	3	284
Brooms and Ivesfield, N. of Oldbury Hill	10	400
Broomsleigh, Chart Farm, and Hider's hop-garden	34	400 to 460
Chart Common	1	510
Chart Lodge	1	434
Crouch	1	380
Claygate Cross	1	350
Crowhurst (and Kingsfield)	9	310
Cop Hall (Belmont), E. of Ightham	1	410
Coneyfield, N. of Ightham Church	4	295
Dunks Green and Shipborne	9	200 to 240
Fane Hill (and Twelve-acres), N. of Ightham	62	310 to 350
Four Vents, near East Yaldham	1	420
Fuller Street	1	400
Goose Green, near Hadlow	1	137
Hadlow, North of	1	110
Hamptons	1	120

* Geology of the Weald, p. 183.
† Ordinary flakes are omitted.

Table (*continued*).

Localities (within 5 miles of Ightham).	Number of recorded specimens.	Height above the sea-level.
		feet.
Highfield (and Islesfield), E. of Ightham	14	300 to 330
Ightham Common and Knoll, and Bellevue ...	3	460
Kilnfield, N.W. of Oldbury Hill	28	415
West Malling	2	190 to 240
Offham (Hook Wood, 310) and E. Comp, 330...	3	310 to 330
Oldbury (East), and Palmer's and Morral's Plantation	17	390 to 420
Oldbury Hill	2	500
Oldbury Place (and Sunnybanks)	5	398 to 400
Patch Grove, North 360, South 400	21	360 to 400
Platt	1	310
Rose Wood, Hop-plantation, and Bradleys	3	490
Seal, the hill west of	11	310
School-field, N.E. of Ightham	46	270
Sheet Hill	1	390
Tyers Knoll and Bassett's Plantation	2	320
Waterden (Seal Hill)	3	420

To these may be added one specimen found by Mr. De B. Crawshay at each of the following places:—Punish Farm, on the Chalk escarpment (600 ft.); Chart Common (500 ft.), and Fawke Common (600 ft.), on the Lower Greensand near Sevenoaks.

The heights given above must not be judged of only in relation to the level of the sea, but rather to those of the adjacent streams, all of which are here considerably above the sea-level. Thus the Shode at Ightham is 260 ft. above O.D., at Dunks Green 145 ft., and at Hampton Mills 117 ft.; while the small tributary of the Darent at Child's Bridge, near Seal, is 230 ft., and that of the Leybourne stream at Malling 80 ft. above O.D. On the other hand, the Lower Greensand hills above Stone Street, and at Oldbury Hill, west of Ightham, attain a height respectively of 673 and 620 ft., and the wooded hills east of Ightham of 552 ft.; the Chalk-escarpment rises to the height of 754 ft., while the Tertiary outlier which caps the Chalk reaches a height of 765 ft. This point has to be considered in the following list, in which the foregoing places are grouped according to the contour-lines of the 6-inch Ordnance Maps.

At and above the Contour-line of 500 *ft.*

Ash; Bower Lane; Punish (these are on the high Chalk plain). The following are all on the Lower Greensand:—Bitchet and Stone Street; Chart Common; Oldbury Hill; Fawke Common.

Total specimens, 46

Between the Contour-lines of 400 *and* 500 *ft.*

Bewley; Brooms and Ivesfield; Broomsleigh; Chart Farm; Chart Lodge; Cop Hall; Fuller Street; Four Vents; Ightham Common; Kilnfield; Rose Wood; Waterden .... Total 211

Between the Contour-lines of 300 *and* 400 *ft.*

Buckwell; Bayshaw; Borough Green; Crouch; Claygate; Crowhurst; Fane Hill; Highfield; Oldbury East; Oldbury Place; Offham; Platt; Patch Grove; Robsacks; Sheet Hill; Seal; Tyers Knoll. Total 139

Between the Contour-lines of 200 *and* 300 *ft.*

Basted; Coneyfield; Dunks Green and Shipborne; School-field; West Malling .... Total 12

Between the Contour-lines of 100 *and* 200 *ft.*

Goose Green; Hadlow; West Malling .... Total 3

Or, arranging them according to the three hydrographical basins to which they belong, they may be grouped as under:—

Within the Basin of the Shode.

Bayshaw and Robsacks; Patch Grove, S. and W.; Twelveacres; Fane Hill; Kilnfield; Ivesfield; Brooms; Styants Bottom; Coneyfield, Oldbury; Court Lodge, W.; Bewley; Sheet Hill; Rose Wood; Ightham Common; Highfield; Platt; Crowhurst; Basted; Claygate; Crouch; Four Vents; Tyers Knoll; Cop Hall; Dunks Green and Shipborne; Hamptons; Hadlow.

Within the Darent Basin.

Bitchet; Broomsleigh; Buckwell; Chart Common; Chart Lodge; Fuller Street; Stonepits; Seal Hill; Waterden; Child's Bridge.

Within the Basin of the Leybourne Stream.

Offham; West Malling; East Comp.

Within the Thames Basin.

Ash; Bower Farm Lane; Punish.

These lists show how wide the distribution of Palæolithic flint implements in the Ightham district is *. It will be seen by reference to the Map (Pl. IX.) and sections that they extend far beyond the limits that I have assigned to the river-drifts formed since the present hydrographical basins were established.

Of the various localities named above, the only ones which, I consider, come within the boundaries of the old course of the Shode, at the time that it flowed at its higher levels, are Fane Hill (the lower part of it), Coneyfield, Bayshaw, Highfield, Crowhurst, Basted, Dunks Green, and Hamptons. Applying the same rule to the adjacent Darent tributary, the known river-drifts are confined to Child's Bridge, and possibly to the terrace just below Fuller Street and Stonepit; and in the Leybourne Valley to West Malling and Leybourne. All the other places are beyond the river-boundaries, and the presence of palæolithic implements at those higher levels must be accounted for by some other means than those in connexion with the former *régime* of the existing streams.

Character of the Flint Implements.—Until the discoveries of Mr.

* It is probable that their distribution is even more general than here indicated; for a certain portion of the land is pasture and alluvial land, which prevents the examination of the subsoil.

Harrison, these abnormal cases were so rare that the few specimens found were hardly the subject of discussion, or were supposed to be, like the Neolithic flint specimens, dropped or lost on the surface of the land, where they had since remained *. It is clear that either such must have been their origin, in which case these flint implements might be of the usual so-called Post-glacial age, or else that they are in some way connected with the drift-beds on the surface of which they are found, or with others since removed, in either of which cases they must be of greater antiquity than the river-valley gravel specimens. The question, therefore, in relation to the antiquity of man, is one of very considerable interest. The first of these two opinions seems to be the one tacitly held; but an examination of the specimens and of the ground makes me doubt whether the presence of the implements can be accounted for in this way. The character of ordinary Neolithic surface-specimens is very distinct from that of these palæolithic forms.

The unpolished Neolithic flint implements that are found on the surface are at once recognized, not only by their form, but also by their condition. The flint is weathered, and the black surfaces have become irregularly whitened, with a dull lustre, and with edges often slightly blunted, but not water-worn. There is an absence also of that uniform but varied colouring which results from entombment in a matrix of a special character. The specimens are free from incrustation, except in a few cases, where they have lain in alluvial beds; while from exposure on the surface they have commonly come in contact with plough or spade, and the iron rubbed off by the sharp edges of the stone has rusted and fringed them with strong ferruginous stains, in contrast with the general colourless surface. The surface of these palæolithic flints, on the contrary, although they occasionally show contact with the plough, are more usually free from these iron-marks, and exhibit generally the deep uniform staining of brown, yellow, or white, together with the bright patina, resulting from long imbedment in drift-deposits of different characters; and while some specimens are perfectly sharp and uninjured, others are more or less rolled and worn at the edges by drift-action, —some very much so.

Of the Flint Implements belonging to the Shode river-drifts †, the greater number are of a brown, yellow, or white colour, patinated, sharp, and uninjured, while others are much worn and rolled. At Bayshaw well-finished light-coloured specimens are found uninjured in a gravelly red clay 4 feet thick. At Fane Hill the specimens are more frequently of the pointed and spear-head type, with a few flakes and scrapers. Some of them are white, patinated, and sharp; a few specimens are rudely made, of a deep brown colour, and very much rolled and worn. These latter seem to be derived.

At Highfield, the specimens, which have no doubt been exposed by

* Or, as suggested by Dr. J. Evans, that these hill-drifts are connected with the existing drainage-system; their independence will be shown further on.

† I have not considered it necessary to figure any of these, as they differ in no respect from the ordinary River-drift implements.

denudation of the bed of gravel, are many of them ovoids, of a bright ochreous colour; a few are plough-stained.

At Dunks Green the specimens are mostly small and well-formed pointed ovoids. One of them was taken from under 2 feet of gravel. These specimens are further of interest, inasmuch as, although now found mostly on the surface, the small but prominent incrustations of iron-oxide and sand with which several, together with the pebbles, are spotted, show that they have lain in a ferruginous matrix and have been brought to the surface by partial denudation of this bed of drift-gravel.

The Implements of the older higher or hill-levels of the Shode basin present characters very similar to the foregoing, except that on the whole they may be somewhat ruder, and there is a preponderance of the smaller and ovoid forms with fewer of the large lance-head type.

On the west side of Oldbury Hill * specimens are found on the surface at Kilnfield, Upper Patch Grove, and Styants Bottom. Some of these are lance-head forms, and others are small well-finished ovoids (Pl. X. fig. 4), sharp and uninjured. The majority are porcellaneous, and with a strong patina. With them are a few large, rough, flake-scrapers. On the east of Oldbury, flint implements have been found between the levels of 400 and 500 ft., and one above that height. They are mostly of small size, light bluish-white in colour, or porcellaneous. Some are pointed ovoids, others thick flakes worked on one side, and a few scrapers.

To the south of Ightham there are a number of the older high-level or hill-drifts, on the surface of which Mr. Harrison has found palæolithic flint implements. It is not necessary to specify all these. As a type of the whole, we take the one locality which has proved most productive, viz. the field west of Bewley Farm, where the ground at a height of from 420 to 430 ft. is covered by a much-weathered subangular chert-drift, with a few subangular flints and pebbles. Out of 23 specimens from this place, taken at random, I found—

6 well-formed pointed ovoids, mostly with a strong *twist*; two of these were yellow and uninjured, and two were white and porcellaneous, and two plough-stained (Pl. X. fig. 7).
7 smaller ovoids; mostly porcellaneous, with a tinge of yellow, some of them plough-stained.
2 small pointed lance-shaped white implements, stained by the plough.
5 more massive pointed implements, white or yellowish, one of which was sharp and uninjured, one patinated, but with the glaze rubbed off its edges and much worn, and two rude specimens damaged by plough.
3 bright-yellow thick flakes, worked at edges and uninjured (Pl. X. fig. 3).

In the Darent Basin the specimens from the high level (530 ft.) of Lower Bitchet are varied in form, are mostly white and porcellaneous, but dimmed, and show but little sign of wear, except by

* The alternation of hard cherty beds with soft sands at Oldbury Hill would tend to the natural formation of rock-shelters, and this, with the defensive advantages of the position, may have attracted the larger population which, from the abundance of worked flints, seems to have centred for a few miles round this conspicuous hill.

the plough in the case of some (Pl. X. fig. 2). At Chart Farm and Stonepit (400 to 440 ft.) the specimens are in general white, small and rude, and with plough-stains (Pl. X. fig. 6). One small specimen ($2\frac{1}{2}$ inches long) is well formed and uninjured. Another pointed specimen is made from a dark-brown subangular flint, the worked surface being of a light greyish-white colour (Pl. X. fig. 1). One lance-head implement is made of a peculiar white granular flint, which I have seen in the Chalk about Fawkham. But few flakes were found. Some of the specimens from this district are much pitted.

Mr. De B. Crawshay has an admirably worked specimen from a Lower-Greensand (Folkestone Beds) pit at Seal Chart Common, at the level of 500 ft. It is a shallow pit, worked for road-metal. The upper cherty beds are disturbed and displaced, and mixed up with white sand and some reddish clay and loam. The specimen was found at a depth of one foot from the surface, and probably, from its aspect, in the red clay or loess, a large body of which occurs at a short distance south, where it has been worked as a brick-earth. This implement (Pl. X. fig. 8) is flat, finely worked to a sharp point and edges, and has a delicate white porcellaneous surface, but the butt end has been broken off. It resembles very closely, both in appearance and workmanship, some of the flint implements from Warean's pit at St. Acheul (Amiens), where they are also found in a reddish clay or brick-earth.

The specimens from Seal are, on the whole, larger and ruder, and many are of the lance-head type. Several of them also are made of the white granular flint just mentioned.

The only specimen recorded from the river-gravels in the Darent Valley is a doubtful rude flake found by Mr. Harrison *in situ* in the chert and flint-gravel at Child's Bridge, about 30 ft. above the stream.

Very few specimens have yet been found in the Leybourne Valley. Those at West Malling were in a bed of flint river-gravel, and at Comp in an apparently older drift of angular chert in a red clay. They are of medium size, pointed, and rude.

The Chalk-plateau Specimens.—Passing to the Chalk hills which drain northward into the Thames, a remarkable spread of flint implements has been discovered by Mr. Harrison on the high plain at Ash, 5 miles north of Ightham, and $6\frac{1}{2}$ miles south of Gravesend. There, at a height of from 490 to 510 ft. above O.D., a small outlier of Lower Tertiary sands, scarcely rising above the Chalk-plateau, covers the Chalk; and on these, again, there is a thin scattering of drift composed of unstained angular flints, Tertiary flint-pebbles, some very subangular much-worn flints uniformly stained of a deep warm brown colour, with a few fragments of Lower Greensand ragstone and Oldbury Stone, and a few rare quartzite pebbles. Mingled with these are scarce palæolithic flint implements. The ground has been carefully searched over by Messrs. Harrison and De B. Crawshay, who have obtained about thirty specimens from these few

acres of ground. They form a distinct group, characterized by their general brown and ochreous colour, extremely rude shape, and worn appearance. Out of twenty-four specimens, taken at random, I found—

7 rude broad flake-scrapers, deep ochreous or brown in colour, much rolled and worn at edges both by natural and by plough wear.
5 very rude pointed implements of a light yellowish-white colour, much weathered as above; one of them is pitted (Pl. XI. figs. 2, 7).
1 small fairly-formed broad-pointed implement; colour and wear as above.
1 ditto ovoid ditto; light yellow patinated, and with an old fracture.
2 very rude thick massive scrapers (?), of a deep brown colour and much worn.
2 flat massive brown flints, slightly wrought, and edges worn as though by hammering.
1 massive green-coated flint, worked on one side to a point and stained brown.
2 deep ochreous thick-backed flakes, worked on one side (Pl. XI. fig. 1).
1 large rude flake (natural?), artificially worked on edges (Pl. XI. fig. 4).

Neolithic implements, retaining in greater part the colour of the original flint and mostly plough-stained, occur on the same surface.

Mr. Harrison has more recently found a few rude implements (Pl. XI. fig. 3) or flakes of a similar character to the above, and associated with similar subangular brown flints and one quartzite pebble, a short distance south of Bower Farm, 1½ mile south-east of Eynsford, and at the contour-level of 510 to 530 ft.; and at the still higher level of 600 ft. Mr. De B. Crawshay has found a massive flake (scraper?), of a very rude make and brown colour, on Punish Farm, near the edge of the Chalk-escarpment, north of West Malling.

Conclusion: Relative Age of the Drifts.—As before observed, there is, in the absence of organic remains, great difficulty in assigning to the several drifts I have described a relative age. Nevertheless, there are physical features connected with them which may enable us to form some approximate conclusion; and the number and character of the palæolithic implements facilitates the attempt, which may at least clear up some of the more essential points.

It is evident from the condition of the implements that, although now occurring on the surface of the ground, they, unlike the Neolithic flints, which are unstained and unaltered except by atmospheric agencies, have been imbedded in some matrix which has produced an external change of structure and colour; while the matrix itself, which has been removed by denudation, has nevertheless in several instances left traces on the implements sufficient to indicate its nature (Pl. XI. fig. 6).

In the case of the river-gravel sites of Highfield and Dunks Green, the question presents no difficulty. There the beds have been partly denuded, and the flint implements which were imbedded in them have thus become exposed on the surface. This explanation may also apply to the implements found associated with some of the drifts higher than those which can be ascribed to the river-period. But there are others to which it will not apply,—such, for example, as those which are found at elevations of 100 to 200 ft., or more, higher than the watershed of the three streams, nearly, in fact, to

the summit of the Lower-Greensand range and of the Chalk-escarpment, where they occur under conditions clearly indicating a different origin.

Although these implements may now lie on the bare surface of the Lower Greensand or the Chalk, yet they are almost always found associated either with the remains of a drift of transported materials or of a brick-earth. Flints from the Chalk, and flint-pebbles from the Tertiary strata overlying the Chalk, accompany the flint implements at Lower Bitchet, Bewley, Crouch, Seal, and other places. These drifts point to a transport from north to south, though with them there is always mixed a certain proportion of local *débris* of the chert and ragstone of the Lower Greensand, the latter often preponderating almost to the exclusion of the others. Worn and stained subangular flints are common in many places, more especially on the Chalk hills.

The implements have a few leading characters which enable us to separate them into three classes:—1st. Those of which the flint still shows a portion of its original colour, and the alteration is not much greater than in Neolithic flints. 2nd. Those of which the surface has been wholly or in greater part altered in structure, has turned from black to white, and has acquired so bright a patina as to give them the aspect of glazed ware, or, as it is termed, a porcellaneous aspect; sometimes the white has a tinge of yellow. These specimens generally show no trace of wear, and are sometimes as sharp as when first made. 3rd. Those of which the flint has also lost its original colour, and has been stained of yellow, ochreous, or brown colours, often very dark, with or without patina. The latter brown implements are generally much rolled and worn, like the brown-stained natural flints with which they are associated.

The characters of the first class call for no particular observation; those of the second and third are so marked that there is no difficulty in referring them each to a distinct matrix. The white porcellaneous aspect is acquired by imbedment in a stiff brick-earth or loess, generally of a reddish colour, as typified in the instance of Warean's pit, St. Acheul, where all the implements from the stiff red brick-earth have acquired this bright white aspect. These white implements also occasionally exhibit dendritic markings. The ochreous and brown coating seems to result from imbedment in particular ferruginous beds of sand or gravel, as in the case of the Shrub Hill (Norfolk) and other localities.

With regard, again, to the 2nd group, I have little doubt that the fine porcellanous specimen (Pl. X. fig. 8) from Seal Chart Common came from the reddish clay or loess, of which a thin remnant fills the uneven surface of the disturbed Folkestone beds. Similar specimens occur in the short deep valley which runs up on the west side of Oldbury Hill by Patch Grove, Kilnfield, and Styants Bottom, although no brick-earth is seen there; but near the head of the valley, at Crown Point, there is a small deposit of brick-earth, in which a large white palæolithic flake was found at the depth of 4 ft. A few porcellaneous specimens have been found on the same level, of

from 400 to 500 ft., on the east slopes of Oldbury. In the Shode-basin Mr. Harrison found, near Crouch Point, at the height of 400 ft., a whitish flint scraper imbedded under 3 or 4 ft. of brick-earth. Similar white and sharp specimens are found on the surface at Bewley, Bitchet, and other places, though no traces of brick-earth are there visible.

I consider it therefore more than probable that all these specimens have originally been imbedded in a brick-earth or loess, which has been denuded away, and that this district had originally a covering of loess, which seems to have reached to a height of 550 ft. and possibly more. Nor are we without corroborating evidence. On the hill between Crowhurst and Highfield there is a bare plateau of Kentish Rag, 344 ft. above O.D. and 144 ft. above the Shode. In passing by, Mr. Harrison informed me that in trenching or ploughing the fields a number of fissures or pipes of a red clay had been met with, while the Ragstone between them presented a bare surface. Now this could only have occurred by the surface having been originally covered by a uniform bed of clay or loess, which, as the Ragstone was rent or worn away beneath it by the passage downwards of the surface-waters, subsided into the cavities so formed, and was there protected from the denudation which subsequently removed the exposed portions of the clay. It is a case analogous to the preservation of Lower Tertiary sands and clays in pipes on a bare Chalk surface, or to that of the Pliocene (Crag) beds on the Chalk-escarpment above Lenham *. For the denudation of such soft beds of brick-earth or loess, the rainfall, especially if heavy and long-continued, as we have reason to suppose it was during the Pleistocene period, might have sufficed for its removal to a great extent, except in the more sheltered places, leaving the heavier flints, which it may have contained *in situ*, on the surface of the denuded ground beneath. No powerful denudation by large bodies of water, or otherwise, is needed to effect this object. It is one common to all time.

A certain number of the third class of implements are found associated with the river-valley and hill drifts, and while some of them may be local and contemporaneous, others appear to be derived from an older drift. These are generally much rolled and worn, and present a marked contrast in make, colour, and wear to the other specimens with which they are associated; not but that we may find in any valley drift specimens showing equally great differences of wear caused by the shingle when drifting in the old rivers; but those to which I allude present other points of difference, which induce me to think that they may be derived from older beds. The type of this class is that afforded by the specimens found at Ash, the bulk of which are, with a few exceptions, singularly rude, of a deep ochreous or brown colour, and generally rolled and worn. They are like in colour, and some almost in wear, to the worn, brown-stained, flint *débris* by which they are accompanied. It is important to note also, as affording a clue to the

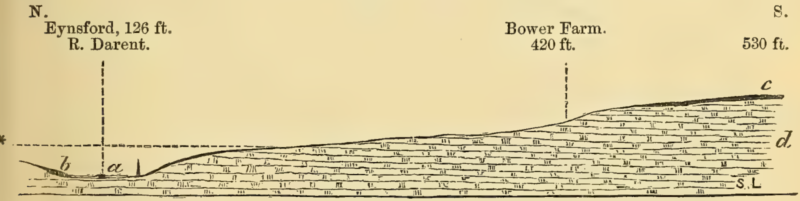
* Quart. Journ. Geol. Soc. vol. xiv. p. 322.

origin of these implements, that although found on the surface-soil, and associated with many comparatively unaltered Neolithic flints, a considerable proportion of these Palæolithic implements are studded on one side with small dark-brown concretionary incrustations of iron peroxide and sand (see Pl. XI. fig. 6). Many of the brown flints have also the same sort of incrustation. From this we may infer that both the flint implements and the flints have at one time been imbedded in a sandy, ferruginous matrix, just as the film of calcite on the under side of some of the St. Acheul specimens shows them to come from one of the seams of calcareous sand or chalky gravel common in the drift there, or as the ferruginous concretions on the Dunks Green specimens indicate their origin in that drift †.

The Ash specimens are not scattered indiscriminately over the chalk plateau, but seem associated with the worn brown flints which here lie on the few acres of Tertiary sands and shingle immediately north of the church, or at South Ash on the "red clay with flints," and would appear for the reasons aforesaid to belong to an old drift-deposit of which only the remnants now remain on the high summits of the chalk plain, the main body having been removed by denudation. Beyond these indications of its former position we have yet failed to detect the original beds; possibly they no longer exist *in situ*.

Precisely similar specimens to the number of twelve or more have recently been found by Mr. Harrison between Romney Street and Bower Farm, near Eynsford, $3\frac{1}{2}$ miles west from Ash, and 520 ft. above O.D. They are there also associated with the brown-stained, subangular, and rolled flints, which there lie on a surface of red-clay-with-flints: they exhibit the same ferruginous incrustation, and are equally rude and misshapen in form as those of Ash. This locality possesses the additional interest that it overlooks the Darent valley with its Postglacial river-drift, and is nearly 400 ft. above the level of the river at Eynsford, and about 320 or 330 above that of the highest river-terrace drift, as shown in the following section (fig. 5):—

Fig. 5.—*Section across the Valley of the Darent at Eynsford.* (Length 2 miles.)



a. Alluvium. *b*. River-drift with tooth of Mammoth.
c. Red-Clay-with-flints, with an overspread of worn brown flints and rude flint implements. *d*. Chalk.
* Highest level of the old River-terraces of the Darent.

† A number of the component pebbles of this gravel have the same iron-peroxide concretionary incrustation.

Still more remarkable is the Punish site, also on the "red-clay-with-flints;" but as only one rude flake has yet been found there, this find requires confirmation. This specimen was found by Mr. Crawshay at the contour-line of 600 ft., while the height of the Leybourne stream just below the escarpment is only 50 ft. above O.D., and that of the river-terrace about 80 to 100 ft. higher.

A few implements of the same character as those of Ash have, as before mentioned, been found in the old river- and other drifts of Ightham. Several, for example, were found in the gravelly loam cut through by the railway at the foot of Fane hill, and in other parts of the Shode valley; these abnormal specimens are, I think, probably derived from this higher chalk-plateau drift.

If we may speculate with the imperfect data before us upon the sequence of events, we find certain landmarks fairly well defined, while the relation between them is yet involved in much obscurity. That the drift-gravels in the Shode valley up to a height of 340 ft. above O.D. at Ightham, and of about 260 ft. lower down the valley at Shipborne, may be referred to the ordinary valley-gravels of Postglacial age, there can be little doubt. It is also probable that the loess is the deposit from flood-waters, though it may be of different dates. Some of it may be referred to the Medway when it flowed at its higher levels, which Mr. Topley has shown to be 253 ft. at Starvecrow, near Tunbridge, and not less than 330 ft. lower down the valley nearer to Maidstone *. This latter is the highest level at which he records the Medway river-gravels †, and its flood-waters could hardly have reached very much higher. How, then, are we to account for drift deposits at the height of 550 ft. and more?

From the circumstance that the "river-drifts," connected with the early *régime* of the Darent, the Shode, and the Medway, do not in any case exceed from 300 to 340 ft. in height above the sea-level, and for other reasons before named, it does not seem possible to connect the isolated mounds of coarse gravel capping the hill at Highlands (388 ft.), at Belmont (420 ft.), and the flint-drift at Bitchet (530 ft.) and other places, with the action of these rivers since they have flowed in the present valley-channels. Whether or not those high mounds of drift-gravel were connected with some form of glacial action before the excavation of the present valley-systems of the Shode, I am not prepared to say, but I think it not improbable. The effect, from whatever cause, has been to carry the flints of the chalk, the flint pebbles of the Tertiary beds, and the stained flint-drift of the Ash plain from off the chalk hills on to hills several miles south of the escarpment.

The "white flint-drift" lying on the Gault in many places at the foot of the Downs, and of which a patch, before described, remains on the watershed between the Shode and the Leybourne stream,

* 'Geology of the Weald,' pp. 178, 185. In the scanty patch of drift at the latter place Mr. Topley found a small flake, which has all the appearance of being of palæolithic age.

† This, however, may belong to the hill-gravels.

affords, however, better evidence of glacial action. This gravel, which consists in greater part of perfectly angular and unrolled white flints, with a few Tertiary pebbles, and occasionally with fragments of chert, is unstratified, and looks as though it had been forced down, irregularly as it were, into the underlying Gault, by pressure from above. The flints are often pitted or pock-marked. The section, however, at Park-Farm brick-pit is small and insufficient. This gravel is better developed and possesses more distinctive characters in other parts of the Holmesdale valley, and I will therefore reserve the fuller account of it to a future occasion, when I shall be able to give more definite reasons for its origin.

I showed *, many years ago, that the great trough or valley of Holmesdale, in which this drift has been deposited, is of more recent date than the extensive spread of "red clay with flints" which lies on the top of the chalk hills. Consequently the brown-stained flint-drift, which has now been traced to the edge of the escarpment, where, like the red clay, it suddenly ends, together probably with the associated rude flint implements, must also be of older date than the valley, and therefore anterior to the Postglacial "river-drifts" of these tributaries of the Medway and the Thames valleys, which lie in them. I have also shown † that there has been, at a time probably before that of the northern drift or Boulder-clay series, a drift from the south which carried the chert and ragstone of the Lower Greensand across the chalk-escarpment into the Thames valley—not in the line of the present river-valleys, but traversing the high chalk plain, and capping the summit of some of the higher hills in the London basin. Still it seems not to be universally distributed, but to keep to certain lines, springing from the lower, but still high, points or gaps in the chalk-escarpment ‡. Amongst the drift-capped hills of the Thames valley is that of Swanscombe Wood, $5\frac{1}{2}$ miles north of Ash, and 306 ft. § above O.D. It consists of an outlier of London Clay, with a capping of this southern drift, which there consists, according to a note I made some years ago of a small shallow section then existing by the Old Telegraph, of :—

Tertiary flint pebbles (Woolwich beds).
Subangular fragments of brown chert ... ⎫
,, ,, of bright red chert ⎬ Lower Greensand.
,, ,, of yellow ragstone ⎭
Subangular flints, not coloured.
Flints, much rolled and worn and stained deep brown.
Green-coated flints (Thanet Sands).

The above are placed in the order of their relative abundance. The brown and red cherts are from the Lower Greensand of the

* "On the Origin of the Sand and Gravel Pipes in the Chalk," &c., Quart. Journ. Geol. Soc. vol. xi. p. 73 (1854).

† Reports Brit. Assoc. York, 1881, p. 621.

‡ Thus far this brown flint-drift appears to be generally associated with rude flint implements; but the inquiry is yet new and needs more extended observations.

§ This is 220 ft. above the high-level terrace of implement-bearing river-gravel at Swanscombe.

Ightham (Oldbury) district. Now as similar subangular fragments of ragstone and Oldbury Stone are found scattered, in places, over the high chalk plateau of the Ash district, the inference is that when this Lower-Greensend *débris* spread over this area a continuous plane descended from the high range of the Lower Greensand down into the Thames valley, and that this valley has since that period undergone denudation to the depth of 300 ft. or more, and the tributary valleys in proportion.

These physiographical changes and the great height of the old chalk plateau, with its "red clay with flints" and "southern drift" high above the valleys containing the Postglacial deposits, point to the great antiquity—possibly Preglacial—of the palæolithic implements found in association with these summit drifts.

In connexion with the subject of all these drifts, another question suggests itself by the manner in which they are distributed. They are not, as we have seen, confined to the lower parts or river-channels of the valleys, but occur in them at all heights on their sides and on the adjacent hills. It is evident, from the mass of material, its weight, and the distances to which it has been carried, that the agencies by which its distribution was effected throughout not only the period of Postglacial work, but throughout the whole period of plain- or valley-excavation—whether fluviatile, marine, or glacial, or whether during Postglacial or antecedent times—were of far greater power than those operating under the present river *régime*, where such work is unknown. Consequently the attempt to measure or to infer the length of time required for the excavation of these valleys (and by inference of all the outer portion of the Weald) by the work done by present rivers, which possess no such transporting power, cannot but lead to a serious misconception of the antiquity of these valley-systems, and prejudice the discussion of the great stratigraphical problems relating to the antiquity of Man. I do not here raise the question of the mode of denudation, which has been largely treated of by Ramsay * and Topley †, but only that of its energy. It is another illustration of a question I have often had occasion to raise.

Although this inquiry tends to carry Man further back geologically than is generally admitted ‡, I would, for the reasons here given and others I have given before §, so close up the time required for the accomplishment of these great physical changes that, instead of calling for more time, I believe that the commonly accepted Crollian chronology should be so curtailed that the age of Man would not exceed, or possibly not equal, that now claimed for him on that hypothesis.

In any case it appears to me certain that the facts described

* 'The Physical Geology and Geography of Great Britain,' 3rd edit. pp. 336–346.

† 'The Geology of the Weald,' Mem. Geol. Survey, 1875, chapter 16.

‡ Evidence to the same effect, but of a different character, has, however, been brought forward by several geologists.

§ Quart. Journ. Geol. Soc. vol. xliii. p. 393.

carry back these rude works of early man to a period long anterior to the "valley-gravels" formed under the present river *régime*; and for reasons already given, but which I hope to develop more fully on a future occasion, they may, I think, prove even to belong to an early stage of the Glacial or Preglacial Period. The condition of the implements themselves is certainly in accordance with the assumption of extreme age, and they bear also the impress of a very primeval art. Many of them are merely rude flint fragments, very slightly fashioned; others seem to be natural flakes just chipped on the edges. Still they show workmanship, and there is a sufficient number of undoubted small pointed forms to corroborate the artificial character of the whole.

Before concluding I may mention that the palæolithic surface-flints in this part of Kent are by no means confined to the Ightham district. Mr. Montgomery Bell, of Limpsfield, has made a large and interesting collection of specimens found in the course of the last five or six years in the district at the head of the Darent valley*, and Mr. De Barri Crawshay, of Sevenoaks, has more recently found similar specimens in that and the adjacent central district. Of these more hereafter.

EXPLANATION OF PLATES IX.–XI.

Plate IX.

Map slightly reduced from the 1-inch Ordnance Map, retaining only such portions of the topography as relate to this paper and the contour-lines. The small figures give the height above the sea-level (Ordnance Datum).

The distribution of the Palæolithic Flint Implements is taken from the large 6-inch map, upon which each find is recorded by Mr. Harrison. The number of dots at each place only indicates their relative number.

The drift beds must be taken with the reserve attached to them at p. 274. The boundaries are only given approximately.

The boundaries of the several formations are taken by Mr. Topley from the Geological Survey Map.

The extent of the Red-Clay-with-flints on the surface of the Chalk hills is also from the Survey Drift Maps. It includes the Red Clay and Brick-earths. The tinted surface gives the breadth of the channels occupied by the old rivers during their earliest stages. This may be somewhat broader than it should be, in consequence of subsequent denudation having thrown back some of the contour-lines. The heights to which the old river-drifts may have extended are limited to the heights to the watersheds.

The small letters refer to the following places named in the paper:—

a. Highfield.	*e.* Rose Wood.	*i.* Patchgrove.
b. Fane hill.	*f.* Broomsleigh.	*j.* Kilnfield.
c. Bayshaw.	*g.* Buckwell.	*k.* Coneyfield.
d. Styants Bottom.	*h.* Tyers Knoll.	*l.* Kingsfield.

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* Mr. Bell informs me that his collection now consists of 179 whole or slightly broken implements; 73 fragmentary implements; 65 fragments of implements, with over 100 flakes. These were all found within three miles of Limpsfield.

PLATE X.

Flint Implements of the higher or "hill-drifts." The specimens are all drawn of the natural size. The numbers in brackets refer to the numbers in Mr. Harrison's collection.

	Level. ft.
Fig. 1 (71). A small pointed implement made from a dark brown drift-flint: Broomsleigh, near Chart Farm	410
2 (203). A rough flake showing on one side the natural surface of the flint; worked at the edges and to a point: Bitchet	520
3 (128). A flake, showing bulb of percussion, trimmed at the edges: Bewley	420
4 (134). A small creamy-white well-worked semi-ovoid specimen from the south-west side of Oldbury Hill. This is a common form...	510
5 (228). A bluish white roughly worked small pointed ovoid specimen from Ightham Knoll. Also a common form	410
6 (311). A round rough scraper, worked on one side, from Stonepit Plain	380
7 (165). A dark yellow, finely-worked, and perfectly uninjured pointed ovoid with a *strong twist*: Bewley	420
8 (Crawshay collection). A finely-worked, thin-pointed, lance-shaped specimen, from Seal Chart Common (see p. 285): white and brightly porcellaneous. It closely resembles a specimen from Warean's Pit, St. Acheul, Amiens: the butt end is wanting......	500

PLATE XI.

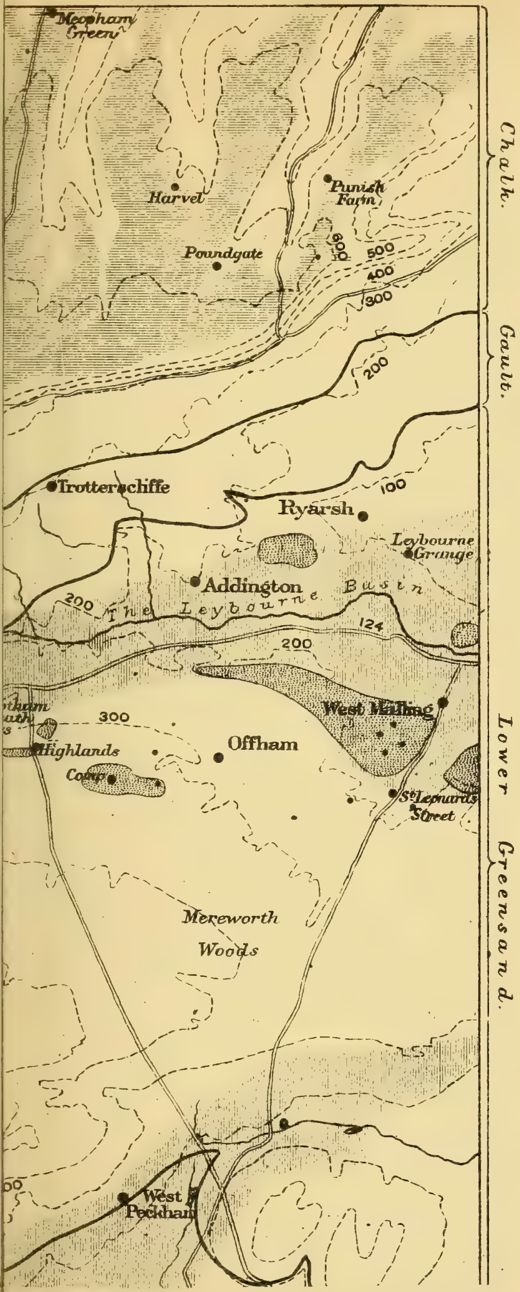
Flint Implements of presumed Preglacial date from the high Chalk plateaux of Ash (A) and Bower Lane (B). These also are of natural size, except figs. 3, 6, and 8, which are reduced by about $\frac{1}{10}$.

	Level. ft.
Fig. 1 (384). A rude flake of brown flint. (A.)	500
2 (419). A roughly made implement of the spear-head type: dirty white, with edges iron-stained by plough. (A.)	500
3 (455). A very rude dark brown roughly pointed and stumpy implement. (B.)	520
4 (464). A large natural flake worked at edges. (A.)	500
5 (348). A flint pebble flaked on one side and slightly worked on edges. (A.)	500
6 (393). A very rude pointed implement, with numerous iron-peroxide incrustations. (A.)	500
7 (406). A very rude spear-head implement of brown flint, pitted, and with iron-peroxide incrustations. (A.)	500
8 (458). A rude flake implement worked on edges, made of a green-coated flint, pitted and worn. (A.)	500

DISCUSSION.

The PRESIDENT expressed his pleasure at hearing a paper containing so careful a chain of reasoning. The large collection of implements from so small an area was remarkable. He asked whether the red clay might not be a subaerial formation, like the deposits formed in such dry countries as Central Asia.

Dr. EVANS congratulated Mr. Harrison on the discovery of the magnificent suite of specimens exhibited. The find was one of much novelty on account of the position of the implements, and the Author's suggestions opened out new and original views There


Meopham Green
Harvel
Punish Farm
Poundgate
600
500
400
300
200
100
Trottersclіffe
Ryarsh
Leybourne Grange
Addington
The Leybourne Basin
124
200
West Malling
300
Highlands
Camp
Offham
St. Leonards Street
Mereworth Woods
West Peckham
Chalk.
Gault.
Lower Greensand.

MAP OF THE DRIFT-BEDS AROUND IGHTHAM.

Scale.
4/5 of an Inch = 1 Mile.

- - - - Contour Lines. Drift Gravels. Palæolithic Implements. Old River Channels. Red Clay with Flints.

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Fig. 1

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Fig. 1
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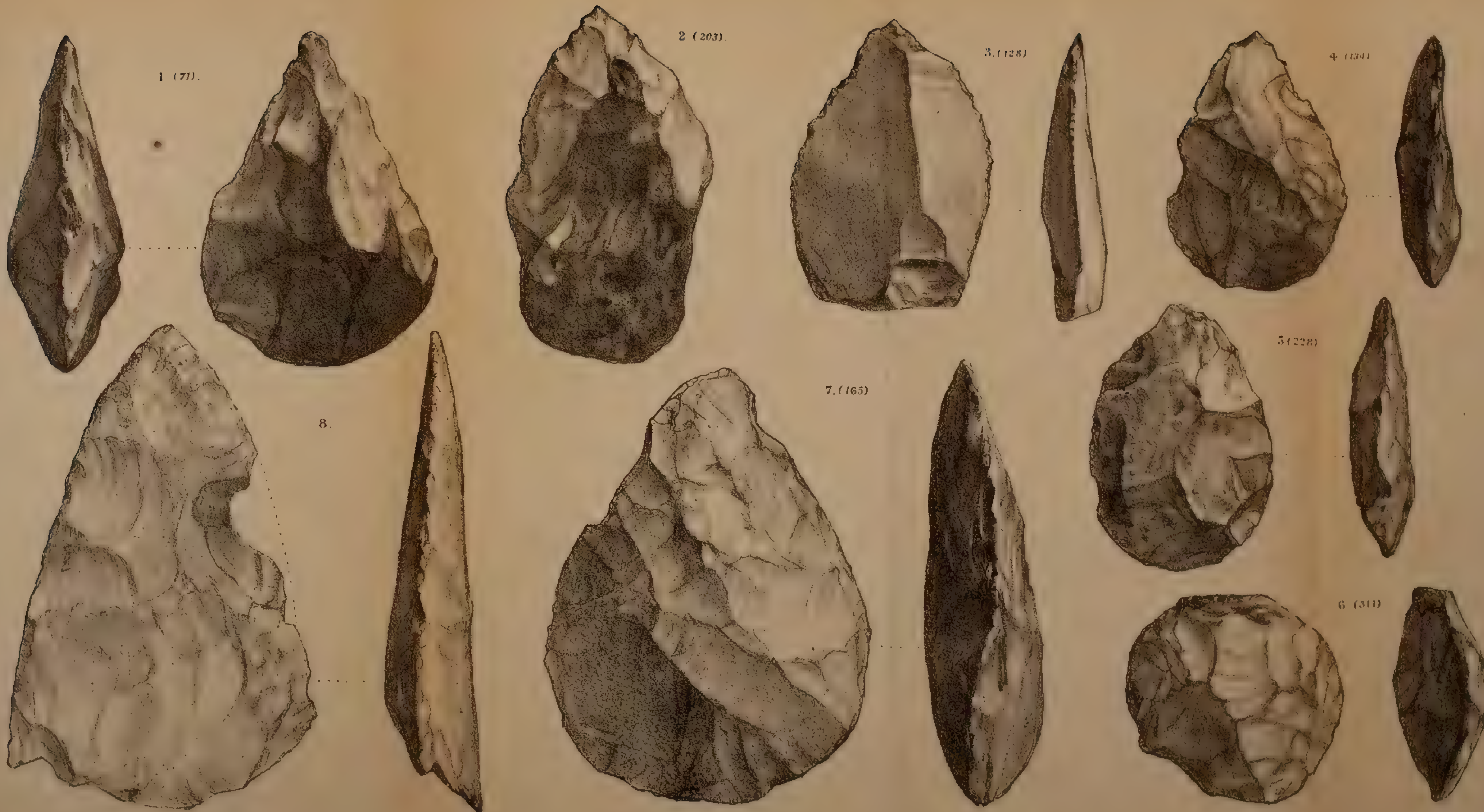

F. H. Michael del. et lith.

Mintern Bros. imp.

FLINT IMPLEMENTS FROM THE HILL-DRIFT.

3.(45

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F. H. Michael del. et lith.

Mintern Bros. imp.

FLINT IMPLEMENTS FROM THE CHALK PLATEAUX.

were, however, one or two points on which he ventured to differ from his old master. He alluded to the enormous amount of change which had affected the ancient land-surface since the implements were formed. At that time the chalk-escarpment was further south. There must then, also, have probably been a greater rainfall, which entirely altered the conditions in a district occupied by such porous rocks. If the east and west valley were filled up to the extent of 200–300 feet, there would even now be streams running from the north where there are dry valleys. He believed that at an early period the gap through which the Darent flowed north did not exist, but that water ran through the east and west valley.

The change of drainage could readily be accounted for if we accepted the proposition that a river in excavating its valley might intersect the source of another stream. If all this were accepted, we might in a great number of cases associate the high-level drifts with fluviatile action. In what Mr. Alfred Tylor had called the "pluvial period," a considerable number of sheets of water or lakes might also have been formed. He admitted the difficulty of associating the deposits with any *existing* water course. On the chalk-downs the red clay was the result of atmospheric denudation. Regarding the Currie-Wood drift, which he had described, he still believed that it might have been formed by a stream running northward. He agreed in the main with the Author's views, but did not accept the classification of the implements into three types, except in so far as they were affected by the matrix. In general form the facies of those from Ash reminded him of a small collection from the gravel of Reading, south of the Thames, from which the good specimens, if any, had been removed. Mr. Bell's discoveries near Limpsfield were also of great interest. When called upon to correlate these Kentish beds with those of the Glacial period, he could not go so far as the Author. He was glad to hear that Prof. Prestwich had more papers to bring forward, and till then he would suspend his judgment as to chronology; as regards closing up time, he thought the Author had used some very doubtful expressions. When we find valleys over a mile wide and 120 feet deep, as at Caversham, and traces of old river-valleys on the site of the present Solent, all cut out since palæolithic times, even allowing for an excessive power in the denuding agents, the subsequent changes must have occupied an enormous lapse of time.

Mr. Topley said that Dr. Evans had well expressed the obligations which the Society were under to local observers.

In the area described they had evidence of the extreme antiquity of certain deposits, as shown by the geological evidence.

In the Somme area the gravels were in the actual valley, and the general explanation of their formation—the gradual excavation of the valley, and the greater antiquity of the higher terraces—was sometimes disputed; but at Ightham it was impossible to bring forward the ordinary objection, for gravels capped the tops of the watersheds. As regards the position of the patches of gravel at Penenden

Heath, we must assume that the chalk-escarpment, as Dr. Evans had stated, did not occupy its present place, so that not only had a considerable valley been excavated by small streams, but the chalk-escarpment had itself receded considerably more than a mile.

He had found a flake in a gravel-pit at East Malling Heath 25 years ago, at a time when nothing of the kind was known in the district; this gravel lies 300 feet above the Medway. It occurred to him that many of the implements lying on the chalk might originally have been dropped there.

Whatever might be the origin of the gravels on the Lower Greensand on the watershed, it is certain that one could, in the Wealden area, work out with extreme accuracy the relationship of the ordinary gravels to the beds from which they had been derived; of this he gave examples, showing how one could sometimes even trace the point of junction of two streams flowing over beds of different lithological characters, and so bringing down different materials.

He described the general distribution of the gravels in the north-eastern part of the Wealden area, showing from their composition that they were formed by streams flowing in the same general direction as the existing streams; the gravels on the east and west sides of the Medway-"gorge" through the Greensand-escarpment, and also on the east and west sides of the Stour-"gorge" through the chalk-escarpment, differ so widely in character, that they cannot be explained by any old river flowing from west to east.

Dr. Hicks was not acquainted with the district, but the Author had brought forward evidence which it was extremely difficult for those who still contended against the glacial or preglacial age of Man in Britain to overcome. He asked why the implements on the upper ridges were rolled. He believed that at the time they were deposited the country formed a plain, and that the evidence pointed to floods coming from melting ice.

Mr. Whitaker commented on the number of implements as indicating a populous condition of our country. He also insisted on the importance of collecting implements in all states of imperfection. Great caution was needed in attempting to correlate the Drifts of Southern England with those of other areas. There was no evidence of the existence of Glacial Drift south of the Thames, though such occurred immediately to the north of it. A large number of the "finds" occurred on the surface, which materially altered the evidence furnished by them. One could not argue as to the age of an implement, unless found in gravel. When the chalk-escarpment occurred at a higher level southward, the springs would also be higher. He was glad to have heard the Author refer to gravels of doubtful age and origin; there were many such, in some of which he would be much surprised to find implements. That at Swanscombe Wood was probably older than the Boulder-clay, though whether older than other glacial deposits he could not say. The term "preglacial" had been used very vaguely, was objectionable, and ought to be dropped.

Mr. Harrison invited Members of the Society to visit the area and examine the district.

Mr. J. Allen Brown agreed with the President as to the subaerial origin of some high-level drifts. He believed that many of the Oldbury-Hill implements were late palæolithic forms. In the Thames valley the height up to which the implements were found and their relation to glacial deposits showed that man then lived in near proximity to the ice.

The Author, in reply, regretted that he must disagree with Dr. Evans as to the flow of the rivers in the direction which he had suggested *. With regard to the erosion of valleys in the Chalk plains we did not find implements of the clumsier type in the valleys, except under such conditions as to suggest their washing down, but on a plateau with the red-clay-with-flints.

He drew a section showing the clay-with-flints ending abruptly against the valleys in which the Postglacial drifts were found. This high-plateau drift could only have been formed when the Chalk extended much further south, as the drift had been derived partly from the denudation of the Lower Greensand. Some of the phenomena seemed to him to be explicable only by ice-action. The implements from Ash were rare and extremely rudely fashioned; many of them showed incrustations of oxide of iron and sand, which could only have been formed when they were imbedded in sand.

* [Mr. F. C. J. Spurrell has suggested that the Darent during its earlier stages rose in the central Weald, and flowed through the Shode valley at Plaxtol, and thus originated the high-level or hill drifts of that valley. One objection, amongst others, to this view is that this high-level drift contains no Wealden débris, whilst, on the other hand, it consists of Tertiary, Chalk, and Lower Greensand débris, all having a transport of from north to south. 'A Sketch of the History of the Rivers and Denudation of West Kent,' p. 11 (Greenwich, 1886).]

17. *On a* Tachylyte *associated with the* Gabbro *of* Carrock Fell *in the* Lake District. By Theo. T. Groom, Esq., B.Sc., Scholar of St. John's College, Cambridge. (Read December 5, 1888.)

(Communicated by Prof. T. McK. Hughes, M.A., F.G.S.)

[Plate XII.]

Whilst engaged in studying the igneous rocks of Carrock Fell I observed a peculiar vein of tachylyte traversing the gabbro close to the point at which the latter passes into the granophyre *. The vein is about an inch thick, and shows well-marked flow-structure parallel to the sides. The centre of the vein is of a pale greenish colour, and shows spherulitic structure, while on each side is a purplish-grey zone. The rock shows a horny or subvitreous lustre, weathers to a yellowish-brown tint, and slightly magnetic; under the blow-pipe splinters fuse readily to a black enamel; the hardness is about 6½. The specific gravity of the whole rock is 2·99, while that of the central zone is 2·95. The average density of basalt-glasses is, according to Messrs. Judd and Cole, about 2·7, that of the Scotch varieties varies from 2·72 to 2·89. The specific gravity of Carrock-Fell rock, it will be seen, considerably exceeds the heaviest of them, but appears to approach that of the continental variolites, such as those of Durance † or Jalguba ‡.

Chemical Composition.

An analysis of the rock has been kindly made for me by Mr. A. R. H. Adie, B.A., of Trinity College, Cambridge. The composition is given below:—

	I.	II.	III.	IV.
SiO_2	53·63	51·66	53·2	51·42
TiO_2	trace.	..	..	..
Al_2O_3	15·93	10·34	8·7	15·39
Fe_2O_3	20·00	23·33	21·8	..
FeO	..	..	..	21·04
MnO	trace.	0·34	..	..
CaO	7·88	6·66	10·3	4·09
MgO	0·78	1·67	..	3·68
K_2O	0·50	..	1·2 (K₂O + Na₂O)	1·07
Na_2O	4·48	..		2·37
H_2O &c.	0·56	3·00	4·1	0·55
	103·76	97·00	99·3	99·61

I. Carrock-Fell tachylyte. III. Basalt of Mt. Gravenaire in Auvergne.
II. Basalt of Beaulieu. IV. Basalt of Steinsberg, near Sinsheim, in Baden.

* Clifton Ward, Quart. Journ. Geol. Soc. vol. xxxii.; and Teall, 'British Petrography,' p. 178.

† Michel Lévy, Bull. Soc. Géol. Fr. (3) v. p. 248.

‡ Tschermak, Mineralog. und petrogr. Mittheilungen, vi. pp. 294, 295.

The percentage of silica places the rock high up in the basic series. It appears to have most affinity with the more acid basalts and with the augite-andesites; this agrees with the conclusions formed from microscopical and other evidence, as well as with the fact that the rock is associated with the Carrock-Fell gabbro, which, according to Mr. Teall *, is the plutonic representative of the andesitic dolerites. The percentage of iron is unusually high, but is parallelled by some continental basalts, analyses of which (taken from Roth's 'Gesteins-analysen') are given above.

Microscopic Characters.

Under the microscope the rock resolves itself into a *ground-mass* of varied constitution, in which are imbedded a limited number of small *porphyritic crystals* or crystal groups. These consist mainly of felspar; augite and quartz are less common, and magnetite (?) is rare.

The *Felspars* are present both as skeleton-crystals and well-developed individuals showing the usual form of plagioclase †. All stages between these two forms are observable. Polysynthetic twinning is common. Occasionally well-formed crystals are honey-combed by a network of glass-inclusions.

The *Augite* is almost colourless, and gives the usual eight-sided sections. Prismatic, ortho- and clinopinacoidal cleavages are present. The angle of extinction is about 39°. Twinning parallel to the ortho-pinacoid occurs.

The *Quartz* is bounded in part by definite crystalline faces, and includes trains of vesicles with moving bubbles. No indications of corrosion by the magma are observable. In one case triangular wedges, apparently of quartz, and closely similar to those of the micro-pegmatite of the neighbouring granophyre, occur in the spherulitic ground-mass in the midst of a group of porphyritic felspars. Such wedges do not appear to have been observed previously in a glass-basis.

The ground-mass consists of a *glass-basis* containing globulites, crystallites, minute crystals, and granules. The glass is of an olive-green colour, and for the most part undevitrified. Distributed through the glass is a series of greenish-brown or reddish granules and minute crystals, evidently of augite. In the smallest of these the double-refraction is very feeble, while the larger polarize brilliantly. The granules may be diffused or collected into *grano-spherites* and *belonospherites*, or they may be united into small polysomatic grains, which, for the sake of brevity, may be termed *glomerites*; and these, like the simple granules, may enter into the composition of spherulitic bodies, and when they predominate, as is very commonly the case, the term *glomerospherite* may be applied to the aggregate. These forms pass imperceptibly into one another.

* *Op. cit.* p. 178.

† Unaltered crystals are not sufficiently common to determine the true extinction-angles; but the few observations that were possible pointed to anorthite as the probable species.

The spherulites are generally surrounded by a clear, sharply defined, isotropic shell. Some of these granular forms closely resemble those of the variolites of Durance. In the occurrence of augite in a spherulitic form the Carrock Fell rock approaches the diabase-porphyrites and variolites. As in the variolites, the sides of the vein and the porphyritic crystals have formed bases of aggregation for the granules. Owing to this tendency, which, according to Rosenbusch, is commonly met with in tachylytes and augite-porphyrites, the central part of the vein has a very complicated structure. Minute granular pyroxenes have formed accumulations round every object in this zone, and have united into thick anastomosing bands, forming an almost isotropic orange-coloured meshwork.

At the very margin of the vein the glass is clear, but soon becomes opaque, owing to the appearance of vast numbers of *globulites, cumulites*, and *margarites*, probably consisting of a slightly titaniferous *magnetite*.

In the substance of the pyroxene meshwork occur a number of small, somewhat irregular, spherulitic bodies. These consist of radially arranged fibres having all the appearance of felspar. The fibres are generally accompanied by granules of augite and small deposits of magnetite. These deposits are often specially developed at the centre of the *pseudospherulite*, where they commonly form a dark nucleus, but may render even the whole spherulite opaque. The cross characteristic of true spherulites is absent. The fibres may be arranged in sheaves, the extinction-angle of which is nearly parallel to their length. It seems probable, from the optical properties of these spherulites, as well as from the analogy of the varioles of the Durance variolites, that the felspar is *oligoclase*. The spherulites have frequently formed round small felspars and skeleton-crystals, and like them are generally surrounded by a deposit of magnetite. Where the spherulites are particularly crowded together their individuality may be lost, and the whole field may be resolved into a cryptocrystalline aggregate of felspathic fibres, granules of augite and opacite showing a complicated arrangement.

The latest development of the rock appears to be a number of close spherical granules of *quartz*, which occur in the clear marginal strip. They often unite into groups and may thus form imperfect prisms and tabulæ. No liquid vesicles are present. Their late origin may be inferred from the fact that they occupy cracks traversing all the zones of the vein. They were evidently formed after the consolidation of the rock had proceeded sufficiently far to allow of the formation of fissures transverse to the direction of flow. The *cracks* have two directions, one series perpendicular, and the other parallel to the sides of the vein; they are apparently due to the shrinkage consequent on cooling of the vein.

Probable Order of Consolidation.

The first-formed constituents of the rock were the porphyritic crystals of the augite, basic felspar, vesicular quartz, and magnetite;

these, together with the skeleton-crystals of felspar, belong to the *intratelluric* period of Rosenbusch. The later *effusion*-period appears to have commenced with the development of numerous granules and glomerites of augite, which were scattered everywhere through the ground-mass. The concentration of these into granospherites &c. in the peripheral part of the vein was accompanied or even preceded in some cases by the separation of iron-ore; but the deposition of the latter mineral was mainly associated with the development of a second generation of felspar of a more acid type than the first: these either formed spherocrystals or united into a complicated network of fibres. Simultaneously, or perhaps rather later, the pyroxene granules, glomerites, and glomerospherites collected along the margins of the vein and around crystals and other bodies. The rock was still fluid, for all the above structures have been modified by flowing of the mass: when the vein began to consolidate, cracks starting from the sides traversed all the zones of the rock, and were filled up by the most acid portions of the magma, which were still in a liquid (or potentially liquid) condition; the last event was the development of a second generation of quartz in the form of clear rounded spherules devoid of vesicles. With the exception of secondary products in some of the felspars and augites, and the slight devitrification (?) of portions of the glass—"metasomatic" changes which were perhaps effected during the period when the gabbro and felsite were regionally metamorphosed—no appreciable change in the rock has taken place since Silurian or, probably, since Ordovician times.

Relation to the Gabbro.

Under the microscope the junction is seen to be somewhat irregular, the glassy magma of the tachylyte penetrating into bays and fjords in the gabbro; the line of separation is nevertheless perfectly sharp. Where the glass penetrates deeply into the gabbro it frequently follows the boundaries of the crystals of the latter, having apparently in such cases simply occupied the space of dislodged portions. Some of the angular fragments of felspar and augite in the glass may represent such pieces broken off and floated away; they never merge into the glass, and discountenance the idea of any assimilation having taken place. This is in harmony with the absence of any corrosive effect on the crystals of the glass, for these seem to be to a large extent the same as those of the gabbro.

At first I supposed the tachylyte to be of later date than the gabbro; but microscopical examination shows such close mineralogical relations between the two rocks that I can only suppose them connected at some point *. An analysis of the gabbro given by Mr. Clifton Ward † would seem not to support this conclusion; but

* The gabbro contains quartz, plagioclase, augite (with prismatic and pinacoidal cleavages), and magnetite or ilmenite, and, in addition to these, diallage, which seems to be the only important mineral not found in the tachylyte.

† Quart. Journ. Geol. Soc. vol. xxxii. p. 24.

the point at which the rock analyzed was taken is at a considerable distance from that at which the tachylyte occurs, and that the rock must vary greatly in composition is shown by the fact that all transitional stages can be observed between the acid granophyre and the basic gabbro at this point.

It seems probable that the tachylyte represents a portion of the gabbro which remained liquid after the rest had consolidated, and, upon fracture of the latter, was injected as a thin sheet into it.

Age.

The evidence as to the age of these associated rocks is unfortunately unsatisfactory, but the following considerations bear on the point:—

The gabbro, in places, shows distinct foliation-banding (flaser structure) * and appears to have undergone regional metamorphism. The strike of the foliation agrees with that of the neighbouring interbedded volcanic series, and it is probable that the movements which resulted in giving the rocks of the Lake district a W.S.W. and E.N.E. strike caused the foliation of the gabbro. The latter, accordingly, already existed in Devonian times, and if really intrusive in the Skiddaw slates must be of post-Cambrian age; it is therefore probably connected with the eruption of the volcanic rocks of the district. Mr. Teall has, indeed, pointed out the resemblance of some of the Carrock-Fell rocks to the Eycott-Hill lavas, and has suggested that the former may be the plutonic representatives of the latter †. The tachylyte is, then, probably of Ordovician age, and, with the exception of the tachylyte observed by the Officers of the Geological Survey ‡ in connexion with the Archæan basic rocks of the west of Sutherland, represents the oldest known British glassy rock of basic composition.

Comparisons with other Basic Glassy Rocks.

The low percentage of silica and the general agreement of the composition of the Carrock-Fell rock with that of certain basalts; the great abundance of magnetite, of skeleton-crystals, and other developmental forms; the minutely granular character of the pyroxene; the tendency of the minerals of the effusion-period to group themselves round those of the intratelluric; the high specific gravity, easy fusibility, and opacity, combine to place it among the basic glassy rocks.

Among these it has affinities with the variolites of Jalguba § described by Loewinson-Lessing ||, and with other glassy forms associated with the more basic augite-porphyrites and augite-andesites, and the more acid basalts. Points of resemblance to these

* This was regarded by Mr. Clifton Ward as bedding.

† *Op. cit.* p. 228.

‡ Quart. Journ. Geol. Soc. vol. xliv. 1888, p. 390.

§ Rosenbusch points out that this rock appears to differ from the typical variolites of Durance, and appends it to the augite-porphyrites. See 'Mikroskopische Physiographie der massigen Gesteine,' p. 234.

|| Tschermak, 'Mineralog. und petrogr. Mittheilungen,' vi. p. 281.

rocks are the occurrence of minute granules and crystals of augite, of porphyritic crystals of felspar, augite, &c., and of felspar spherulites. The tendency of the iron-ore to collect round the skeleton-forms is well marked in the diabase-porphyrites. In the glassy character of the vein the Carrock-Fell rock resembles some of the glassy forms of augite-porphyrite and some basalt-glasses.

But the rock to which the Carrock-Fell tachylyte most nearly approaches appears to be the typical variolite of Durance *. It agrees with this rock in the presence, nature, and behaviour of the varioles (spherulites), in the nature of the pyroxene-granules, and in the presence of a green ground-mass. An important difference, however, from this type is the glassy condition of the ground-mass. This, in all typical variolites, is not isotropic, but contains numerous minute particles of chlorite, often associated with actinolite and epidote. These Rosenbusch holds to be of secondary origin, and Mr. Cole has lately suggested that variolites are altered tachylytes †. The Carrock-Fell tachylyte seems to support these conclusions, the primitive glassy condition having been to a large extent preserved.

There are, however, other points of difference which are original. Of these we may mention the frequent association of the variolites with magnetite, which often renders them more opaque than the surrounding ground-mass; the occurrence of well-developed porphyritic crystals of plagioclase, augite, and quartz, and of quartz-spherules in the ground-mass; the mode of occurrence of the rock; and its association with a quartz-bearing gabbro.

The Carrock-Fell rock is thus referable to none of the species of tachylyte hitherto described, and may perhaps be regarded as a *quartz-gabbro-vitrophyrite*.

Conclusions.

The Carrock-Fell tachylyte is a basic glassy rock associated with a quartz-gabbro, and consisting of a well-preserved, globulitic, and crystallitic glass-basis containing spherical granules of quartz, spherulitic felspars, and a series of pyroxene-granules and granular aggregates, which likewise frequently assume a spherulitic form. It is rendered micro-porphyritic by the sparing development of crystals (or skeleton-crystals) of quartz, felspar, and augite. Owing to the mode of development and to the variety of its constituents it possesses a very complicated structure. It shows resemblances to the glassy forms (variolites) associated with euphotide, and to those associated with less deeply seated basic rocks.

In conclusion, I must express my best thanks to Messrs. Hill and Bonney for the loan of specimens and slides of variolite, to Messrs. Judd, Cole, and Davies for opportunities of examining specimens of variolite in their museums, and to Mr. Harker for several useful suggestions as to the mode of investigating the rock.

* Rosenbusch, *op. cit.* p. 227.
† Quart. Journ. Geol. Soc. vol. xliv. p. 307.

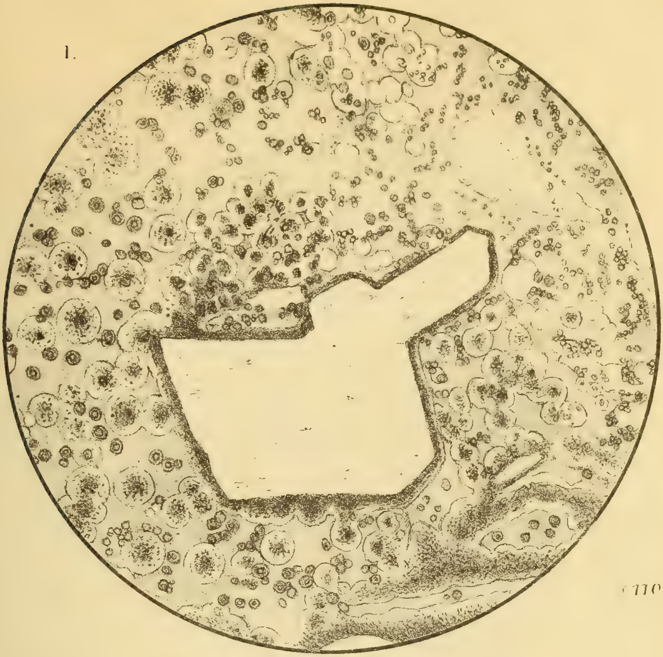
EXPLANATION OF PLATE XII.

Tachylyte from Carrock Fell.

Fig. 1. Marginal portion of the vein, showing crystals of felspar, quartz spherules, glomerospherites, and granules of pyroxene, imbedded in a green glassy basis. × 110.

2. Central portion of the vein showing spherulites and skeleton-crystals of felspar imbedded in an orange-coloured network of finely granular pyroxene, in the meshes of which the green glassy ground-mass with dark pyroxene-grains is seen. × 48.

1.



×110

2.

×48

F.H. Michael lith.

Mintern Bros. imp.

TACHYLYTE FROM CARRICK FELL.

18. NOTES *on the* GEOLOGY *of* MADAGASCAR. By the Rev. R. BARON, F.L.S., F.G.S. *With an* APPENDIX *on the* FOSSILS, by R. B. NEWTON, Esq., F.G.S. (Read March 6, 1889.)

[Communicated by the Director-General of the Geological Survey.]

[PLATES XIII. & XIV.]

GENERAL DESCRIPTION.

MADAGASCAR is as yet almost a *terra incognita* to the geologist, nothing, so far as I am aware, but notices of the most fragmentary kind ever having appeared in regard to its geological features *; and, indeed, until the country is surveyed by competent men, we must be content with descriptions of the most general character. In the absence of something more complete, I present the following notes, drawn up from personal observation, to which I have added here and there a few remarks taken from other sources, as a slight contribution to our knowledge of the geology of this great island.

The central portion of Madagascar is generally regarded as consisting chiefly of granite. Mr. Wallace, for instance, in his 'Island Life' (p. 384), says of it: "A lofty granitic plateau, from 80 to 160 miles wide, and from 3000 to 5000 feet high, occupies its central portion, on which rise peaks and domes of basalt and granite to a height of nearly 9000 feet;" and in the same book there is a physical sketch-map in which the whole of the interior of the island, from about 14° to 23° S. lat., is represented as an "elevated granitic region." Now if we use the terms "granite" and "granitic" in a wide and popular sense, and include in them the various members of the crystalline series of rocks, the description may be regarded as correct; for by far the greater part of the eastern half of Madagascar consists of gneiss and other crystalline rocks, though gneiss very largely predominates. Granite occurs frequently in the form of bosses and, in some places, apparently intercalated with the crystalline schists; diorite is also frequently met with, but gneiss is certainly the prevailing rock. The area occupied by these crystalline rocks, though not precisely known, reaches on the east as far as the coast; on the west it extends, in some places at least, as far as 46° E. longitude †; and it runs in a northerly and southerly direction from about 13° 50′ to 24° S. latitude. In other words, the region occupied by these crystalline (chiefly metamorphic) rocks has a length of about 730 miles, and an average breadth of probably not less than 150, being a total area of over 100,000 square miles. Indeed it is not at all improbable that the area may cover as much as 130,000 square miles. Fully a half of the island, therefore, and that the eastern half, consists of

* The MS. of the present paper was prepared long before Cortese's contribution in the Bollettino del R. Com. Geol. 1888, Nos. 3 & 4, was published.

† Its most westerly limit is probably about 45° 50′.

great and monotonous stretches of gneiss, interspersed here and there with other metamorphic rocks, and occasionally granitic bosses, basaltic masses, and volcanic cones.

The strata have been plicated by lateral pressure into numerous anticlinal and synclinal folds or mountain-waves, the dominant axes of which, as also the strike of the rocks of which they are composed, run about 15° to the east of north, or in a direction parallel with the eastern sea-board, and also corresponding with the longitudinal axis of the island *. Hence the roads from Central Madagascar to the east run over an endless series of more or less parallel hill-ranges, while those to the north and south pass along valleys or comparatively level country. These mountain-waves attain their highest elevation at a distance of about 60 or 70 miles from the east coast, where they run in a linear direction nearly north and south for probably 800 miles or more. Here is situated the great watershed of the island, and from here also the folds of rock gradually dwindle into undulations of smaller dimensions, until finally they disappear below the Indian Ocean on the eastern side, and on the western pass under Secondary and Tertiary formations, of which something will be said by and by.

The great dorsal ridge which forms the watershed of the island consists of gneiss, with a dip towards the west at an average angle of probably 30°; for a great part of its course the ridge has on its eastern side a steep declivity of about 1500 feet. About 20 or 30 miles east of that portion of the ridge which bounds Imerina there runs for some distance another ridge more or less parallel with it, but with the dip of the gneiss apparently to the east, and between the two ridges there is a more or less level plain or valley, which extends, with few interruptions, for about 130 miles, the southern half being known as Ankay, and the northern as Antsihanaka. This longitudinal valley has served as a receptacle for the accumulation of water and detritus, brought down chiefly from the high ground to the west, in fact it has formed the site of a lake. In an article in the 'Antananarivo Annual' for 1885 I made the following remarks with regard to this great valley:—"The largest plain in Central Madagascar is that of Ankay. . . . This plain, now cut and scored by the river Mangoro and its tributaries, forms the bed of an ancient lake, which once extended for a distance of probably 30 or 40 miles, running in a direction north and south between two lines of hills. Alaotra in Antsihanaka (about 20 miles long by 4 or 5 wide) is perhaps the remnant of this ancient lake or, at any rate, one in serial connexion with it." Towards the end of the year 1886 I passed through the plain of Antsihanaka, and found that, not only were my conjectures correct with regard to the former extension of the lake, but that the reality far exceeded even my conjectures. In fact I discovered undoubted evidence that this ancient sheet of water originally reached at least as far north as latitude 15° 30′ in

* It is of interest to note that the dominant strike of the crystalline schists in Eastern Africa is more or less parallel with that of the same series of rocks in Madagascar.

the district of Androna; how much further north I cannot say. And as its southern extremity extended to about latitude 19°, its total length has once exceeded 200 miles. Its breadth, however, has been small compared with its length, averaging probably from 20 to 30 miles. Lake Alaotra is situated in the deepest part of this great longitudinal trough, and is 2600 feet above the sea. It is a shallow sheet of water almost adjoining the eastern range, with weeds reaching to the surface almost throughout its whole extent, and, I may add, literally alive with water-fowl. To the north-east of Mandritsara there is another small sheet of water; this is probably also a remnant of the same ancient lake.

At a slight elevation above Lake Alaotra, on the southern and western sides, there is an extensive marsh, succeeded a little higher by a marginal plain. Above this, again, level surfaces at various heights may be observed, showing how far the water has once extended. Against the western hills, however, old lake-terraces, several hundred feet high, may be distinctly traced; and away again to the north of Antsihanaka there may be seen numerous old lake-bottoms, containing rounded, water-worn, quartz pebbles and small iron nodules. Indeed I traced these old lake-bottoms to over 100 miles north of Lake Alaotra, and found that one of them actually reached to the astonishing height of 1140 feet above the surface of the existing lake. They were to be seen also at various intermediate elevations. The highest and therefore the longest exposed of these lake-bottoms were so much worn by denudation as to be almost unrecognizable, but the existence of numerous water-worn pebbles and, in some places, of deposits of iron ore, bore witness to their character.

About 15 or 16 miles to the south of the town of Mandritsara there is an abrupt break in the western hill-range, the northern end of it forming the mountain of Ambiniviny, which rises as a magnificent precipice to the height of about 2000 feet above what may be called the Mandritsara valley. This precipice is continued for some miles in a semicircular form in a north-west direction.

The old lake-bed runs past Ambiniviny somewhat to the east of it, but in its northern prolongation occupies high ground, and is not so distinctly hemmed in by hill-ranges; indeed on its western edge, which is about 3000 feet above the sea, there is a steep descent of nearly 2000 feet into the Mandritsara valley. Moreover the old lake-bottom is here about 300 feet lower on its eastern side than on its western. In some parts of the beds east of Mandritsara there are very numerous tubular burrows, from $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter and a foot or more long. These are filled with ruler-like hardened earth, which may be taken out in cylindrical pieces. Have these been the homes of some burrowing animal?

Four or five years ago I found imbedded in some ochreous ironstone in the Ankay part of this old lake-bottom (for bog-iron ore abounds in it) a goodly number of fossils, being chiefly the stems of what were probably species of *Cyperus*, leaves, and a depresso-globose fruit about the size of a marble, five-celled and five-seeded. In some

portions of the rock the fossils of leaves were exceedingly numerous, one of which I recognized as that of *Calophyllum parviflorum*, Bojer; and another, judging from its veining, seemingly belonged to the Natural Order Melastomaceæ, and not improbably to the genus *Medinilla*. These had been washed down into the lake from the forest on the western hill-range, where to this day the former plant, as well as various species of *Medinilla*, are still found.

It remains only to add with regard to this old lake-bed that it has been considerably worn by various rivers and streams, notably the Mangoro in Ankay, and the Mandremoka in east Androna, into a system of hills and valleys, many of the latter being now well wooded, so that its original features have become, in many places, so effaced as to be almost unrecognizable.

At Antsirabe, about 40 miles south of the capital, there is the dried-up bed of another ancient lake, but of much smaller dimensions than the one described above. As there are extinct volcanoes near, this ancient lake may not improbably have owed its existence to former volcanic action. It was in the bed of this ancient lake that Dr. Hildebrandt a few years ago discovered the semifossilized bones of a Hippopotamus, which is now extinct in Madagascar, but which was probably in existence at no very remote period, since there is still a native name for the animal (*Lalomena*). Whether this is the same species of *Hippopotamus* (*H. Lemerlei*) as that found by M. Grandidier in the south-west of the island, I cannot say, but not improbably it is. In some places, where the streams have excavated the dried-up bed of this ancient lake, there may be seen layers of lapilli and volcanic sand.

Crystalline Schists, &c.

I have said above that the dominant strike of the crystalline rocks is about 15° to the east of north; but we naturally expect to meet with local variations in a country which has been subject to such vast disturbances as Madagascar, and these we find. For instance, a few miles north and north-west of Antananarivo, the strike and direction of the hill-ranges (Andringitra, Ampananina, &c.) is mainly east and west, with the dip towards the north at an angle of about 35° or 40°. These ranges apparently commence somewhere in the neighbourhood of Ambohimanga, and run west for a distance of 60 or 80 miles. In one part of their course the strata become vertical or nearly so; this occurs a little to the north-west of Ambohibeloma, where there is a sharp ridge or series of ridges, the highest of which forms the mountain of Ambohitrondrana, 30 or 40 miles W.N.W. of Antananarivo.

In some localities these ridges of gneiss, in consequence often of the tilting of the strata at a high angle, present remarkably jagged and serrated outlines, and are striking in their grandeur. This is specially true of the mountain of Vavavato, about 60 miles to the south-west of Antananarivo.

The gneiss *, in many places, is of so highly metamorphosed a character that, at first sight, one would conclude it to be granite; but an examination of other portions of the mass soon reveals its nature. In and about the capital, for instance, the gneiss, which is hornblendic, is generally so highly metamorphosed that, without due care, its real character may be overlooked, as, indeed, is shown by the fact that it is almost always spoken of as granite. It may be called granitic gneiss. Still the rock, in certain parts of the island, even where comparatively large sections are exposed to view, presents such a massive character, not having even the slightest trace of foliation, that, could one feel sure that its texture were the same throughout the mass, one would unhesitatingly speak of it as granite. Frequently the rock appears as though it were very slightly streaked, and may be called granitic gneiss.

The gneiss, being so abundant and covering such a wide area, is, as might be expected, various in texture and mineral composition. For many miles round the capital it is chiefly of a greyish or bluish colour, while in the mountains of Antaramanana and Vavavato and other places it is reddish or pinkish, owing to the flesh-coloured orthoclase contained in it. A great deal of it, moreover, is hornblendic, while in some districts, notably about Lake Itasy, it is garnetiferous, the garnets belonging to the species almandine. They are of the kind known as Cape garnets, but are of no commercial value. As for the mica contained in the gneiss, it seems to be chiefly biotite. Muscovite, however, exists abundantly, and may be sometimes found in plates several inches in length.

The most abundant of the accessory minerals existing in the gneiss is probably magnetite. This is found in such quantities in certain localities as to render observations taken with the prismatic compass totally unreliable. In the part of the country east of Imerina known as Amoronkay, which is on the western flanks of the great hill-range spoken of above, this magnetic iron is specially abundant. It is here that the natives, after separating it from the gangue by washing, work it in their rude way, manufacturing chiefly spades, which are taken for sale to various parts of the island. It is also worked in the same way in Eastern Betsileo, the beds there being probably only a continuation of those at Amoronkay. Abundance of magnetite is also found a little to the west of Ambohibeloma (near the village of Anjamanga), about 40 miles to the west of the capital; at Ambohitrandraina hill and Ambohimanoa mountain, ten or a dozen miles to the north-west of the capital; in Antsihanaka, to the north of Lake Alaotra; and in many other places. Indeed there are many localities where it is so abundant that, were there coal to be found anywhere in its neighbourhood, it might be expected to form at some future day a great source of wealth. It exists, in fact, in grains in the rock, in greater or less proportion, throughout the whole of the area occupied by the gneiss, and by its oxidation imparts the red colour to the soil. In

* A petrographical description of several varieties is given in the accompanying paper by Dr. Hatch (pp. 340, 341).

some places nodules of this magnetite are found almost as large as one's fist. In certain localities, notably in West Valalafotsy, the country is covered with innumerable pebbles composed of quartz and magnetite, so much so, indeed, as to render walking difficult. Sometimes one may meet with a kind of ferruginous conglomerate, formed by the percolation of water charged with iron through sand and pebbles. This conglomerate may often be seen by stream-sides; but in some places away from streams it is found in considerable quantity. In the valley between the villages of Isoavinimerina and Ambohimandray in Imerina there is a bed of pisolitic iron-ore, which the natives know as *tai-mamba* or *taolan-tany* ("crocodile-dung," or "bones of the earth").

Iron pyrites also exists as an accessory mineral in the gneiss. This may frequently be seen in small glittering specks in freshly fractured surfaces of the rock. Large cubical crystals are found in certain localities. Molybdenite is also an accessory mineral occasionally to be met with in the gneiss.

In descriptions of the central provinces of Madagascar we not unfrequently see it stated that there exist extensive deposits of clay. Dr. Mullens, for instance, in his 'Twelve Months in Madagascar,' several times mentions such deposits. In 'The Great African Island,' too, it is said:—"A very large extent of this portion of Madagascar is covered with bright red clay through which the granite and basaltic rocks protrude." The same statement is repeated in Mr. Shaw's book, 'Madagascar and France.' This clay, however, is merely the decayed rock, chiefly gneiss, reddened with the oxidized magnetite above alluded to; and from the fact that foliation of the gneiss is not always entirely obliterated in the decayed portions of the rock, Dr. Mullens has been tempted to call it "sedimentary clay." This decay or weathering of the rocks has, in some places, reached an enormous depth. In one locality north of Andringitra I found that the gneiss had decomposed into clay to a depth of 180 feet. It is owing to this decomposed condition of the rock that the heavy rains in the wet season scoop out those deep and unsightly ravines in the hill-sides which are so common in the interior of the island, and which are occasionally used as cattle-pens by fencing in the lower end. This weathering, moreover, explains the occurrence of those large "boulders" which may frequently be seen, even on hill tops, and which have been more than once considered as erratic blocks due to glacial action, but which, of course, are merely masses of hard rock rounded by weathering that have hitherto resisted decomposition. It may perhaps be worthy of notice that the gneiss, a little to the north of Marotandrano, in the district of Androna, weathers, in some places, into spheroidal forms of a foot or more in diameter.

The other members of the crystalline schists are of much less frequent occurrence than the gneiss, and as yet comparatively little is known either as to their locality or their exact mineral character. Such data, however, as I have been able to gather, imperfect though they be, are here given. Clay-slate is found at least in one locality

in the region of which we are speaking, that locality being somewhere to the west of Ambositra in Betsileo (at Ambohimahazo in Manandriana ?), about 90 or 100 miles S.S.W. of Antananarivo. The slate has been employed in the roofing of the Palace Church in the capital. A rock found in some places—on the mountains of Ambohimanoa, Ambohimiangara, and Karaoka (north of Ifanja marsh), for instance—and known as *vatodidy*, is used occasionally for ornamental purposes in building and also for native lampstands. It is a reddish rock showing banded structure, and may possibly be a kind of decayed gneiss. At Isoavinimerina near Ambohimanoa there is a pulpit made of this *vatodidy*. Hornblende-rock exists close to Ankazobe in Vonizongo, on the west (?) side of the village, and probably at Ankaraoka, near the mountain of Vombohitra. Actinolite-rock and asbestos seem to be common in some parts of Vakin' Ankaratra, the former existing also at Belavenona, about halfway between Antongodrahoja and Amparihibe. Mica-schist is found in various districts, especially in Western Imerina and Vakin' Ankaratra. Chlorite-schist may occasionally be met with. Kyanite-schist likewise occurs. Besides these there are found crystalline limestone, quartzite, and graphite. One locality where crystalline limestone may be seen is about a mile to the south of Ambohimirakitra, seven or eight miles south of the capital. While some of this limestone is in amorphous or only partially crystalline masses, other portions of it are coarsely crystalline. It is found also near Mandritsara, a little to the north-west of the town, and also in the neighbourhood of the mountain of Ambohidraboja (near Mandritsara), where it contains small grains of graphite and talc (?). A reddish crystalline limestone with disseminated scales of what is probably chlorite is found in Antsihanaka.

Among the localities where quartzite occurs may be mentioned Ambohimanga* (to the north of Antananarivo); the hill of Ambohitrandraina; the south-west foot of Ambohimanoa mountain (on the west side of the river Ikopa); Anjamanga (to the west of Ambohibeloma); the north-east end of Ifanja marsh; Anjanahary (in the north-eastern suburbs of the capital); Ambohimirakitra, where the white crystalline limestone occurs; Antanifotsy, in Vakin' Ankaratra; Tsarahafatra, to the north of Imerina, where the rock is schistose; and many other places.

As for the graphite, which the natives know as *manjarano*, *anjamanga*, or *vanjahilatra*, it may be met with in small quantities in all the places mentioned above where quartzite occurs. It is also found in the hill of Ambohidraboja above mentioned, in various localities in Betsileo, and to the west of the mountain of Vavavato. The thickest bed of graphite that I have seen is that near Ambohimirakitra, mentioned above. The natives use it in polishing certain of their rice-pans and dishes.

It is scarcely necessary to say that quartz-veins, sometimes of

* The quartzite here contains scattered scales of a talcose mineral.

great thickness, frequently occur among the other rocks. Of quartz itself many varieties are found, as (*a*) rock-crystal (for large crystals of which Madagascar has been well known for more than 200 years*); (*b*) pale blue vitreous quartz, occurring in Antsihanaka; (*c*) rose quartz, found on the eastern flank of the hill range of Famoizankova, in west Valalafotsy, and in Antsihanaka; (*d*) smoky quartz, which occurs in Antsihanaka; (*e*) milky quartz, a beautiful snow-white variety of which exists at a spot between Ankazobe and Maneva, in Vonizongo; (*f*) jasper, found on the mountain of Vavavato; (*g*) amethyst, which occurs in many localities; (*h*) agate, found in Antsihanaka and on the west bank of the River Betsiboka, south of Mahabo.

Granite.

Here and there the vast stretches of gneiss and its allied rocks are invaded by masses and bosses of granite. The mountain of Vombohitra, situated about 70 or 80 miles north of the capital, is, perhaps, the most remarkable of these eruptive bosses. This mountain is of a circular shape, is perhaps eighteen miles in circumference, and rises boldly, with inaccessible sides in many parts of it, to a height of about 1000 feet above the surrounding country. The granite is of a reddish or pinkish colour, having flesh-coloured orthoclase and black mica †. Within a short distance of this immense granitic boss there is found a coarsely crystalline variety of graphic granite, probably existing in veins running out from Vombohitra. There is also to be found graphic granite on the north side of Vavavato mountain.

Granite similar in appearance to that of Vombohitra also occurs rising in the hill-range known as Famoizankova, on the western confines of Imerina, to the west of Valalafotsy, where, in its contact with the gneiss on its eastern border, abundant large crystals of black tourmaline have been developed. It exists also from about ten miles east of the capital to within three or four miles of the large forest—from about Isoavina to near Mantasoa, covering an area of perhaps 15 or 16 miles in diameter—where it rises in numerous rounded or cupola-like masses, of which Ambatovory, Ambatomanga, &c., are examples. In this region the rock for the most part contains porphyritic crystals of orthoclase felspar. These crystals near the edge of the granite (at least on the northern boundary, which alone I have seen) run more or less in a linear direction from east to west, and, I believe, parallel with the strike of the gneiss in the immediate neighbourhood. This direction of the felspar crystals is due to fracture along the margin of the intruding mass, producing a kind of fluxion-structure on a large scale, the crystals having been obliged to rearrange themselves in

* I have heard of a specimen of rock-crystal containing liquid-cavities $\frac{1}{8}$ or $\frac{1}{4}$ inch in diameter.

† For description of this granite see Dr. Hatch's paper, p. 341.

the direction of least resistance; hence their longer axes are more or less parallel with each other. This peculiarity may distinctly be seen about Ambatovory. Granite is also found a little to the south of Mevatanana; at and about the village of Votovorona (or Soandrariny), between the capital and Fianarantsoa; in the bed of the river Mananta, on the road from the capital to Antongodrahoja; and dykes of it appear near Tsirangaina, a few miles to the south-west of the capital, and near Ambohipiara*, about a dozen miles north-west of the capital. At Vombohitra, Famoizankova, and the locality to the east of the capital, the granite is evidently eruptive; but in the other places mentioned (except, of course, where it occurs in dykes) I should be inclined to regard it as metamorphic, for it seems to be confusedly intermingled with the gneiss, and shades off into it so imperceptibly that it is often quite impossible to say where the granite begins and the gneiss ends.

About fifteen miles to the north-north-west of Mandritsara (immediately to the south of the village of Ambohitromby) there are one or two dome-shaped bosses of what is probably eruptive granite †; and the gneiss near the junction has been altered by contact with the heated mass, the alteration having been accompanied by the development of various minerals.

Older Volcanic Series.

Let us now proceed to notice some of the volcanic pheuomena of the region. The scene of the greatest display of former volcanic activity in Central Madagascar has undoubtedly been Ankaratra. This mountain, situated some twenty to thirty miles to the south-west of Antananarivo, is the highest in the island, attaining an altitude of nearly 9000 feet above the sea. It is a broad and elevated mass of land, with no very sharp peaks or ridges, and having, for the most part, a gentle slope of 4°–8° on all sides, so that it is not easy to define its exact limits. Roughly speaking, however, it may be said to cover an area of perhaps fifty square miles. Now there can be no doubt that Ankaratra is the wreck of a huge, but ancient, subaerial volcano. There are at present, so far at least as my observations go, no traces of cones or craters, but there are volcanic ejectamenta scattered about which bear witness to their former existence. From this volcano vast floods of liquid lava have issued and overflowed the surrounding country to the extent, probably, of from 1500 to 2000 square miles. In fact, almost the whole of Vakin' Ankaratra province has been covered by a sheet of lava. This lava has been poured out at various times, several beds being superimposed on one another. Some of the lava-streams are probably no less than twenty or twenty-five miles in length, and, before they thin out, from 300 to 500 feet in thickness. They are mostly of a basaltic character, chiefly compact, though occasionally

* Described by Dr. Hatch, p. 342.
† Also described by Dr. Hatch, p. 342.

cellular. Here and there basaltic columns may be seen, some of which are now decomposing into wacke. In some places, too, there are extensive sheets of a red ferruginous conglomerate. Some portions of the basalt are amygdaloidal; and in one specimen, which I believe is from Ankaratra, the cavities are lined with radiating zeolites. Some of the basalt is also porphyritic with augite, and also with small crystals of an amber-coloured mineral (possibly zircon), which is infusible before the blowpipe. But besides basalt, there may be found, lying in the bed of some of the streams running down the sides of the mountain, pieces of vesicular trachytic lava, the erupted fragments of the now extinct volcano. The three highest points of Ankaratra are Tsiafajavona, 8494 feet above the sea; Tsiafakafo, 8330 feet; and Ambohitrakoholahy, 7730 feet*. Tsiafajavona, the highest peak, and Tsiafakafo consist of olivine basalt, Ambohitrakoholahy of sanidine trachyte †. But black compact basaltic lavas certainly constitute by far the greater part of the mountain.

It would be interesting to know at what period of Tertiary time Ankaratra was in a state of eruption; but our knowledge of the mountain and the surrounding district is, as yet, too scanty to help us to any conclusion on the matter. There is evidence sufficient, however, to show that the volcano is of ancient date; for, in the first place, all signs of craters or cones seem to have been effaced through denudation, though the presence of fragmentary materials (which, however, have largely disappeared) manifest their former existence. Then, again, numerous deep valleys have been excavated out of the hard basaltic covering by the many streams that come down from the mountain, leaving long tongues of lava diverging from the central mass. Many of these streams have cut clean through the beds of lava, bringing into view the gneiss upon which they are superimposed.

Some thirty or forty miles to the south of Ankaratra there are to be seen about a dozen remarkably conical hills without craters. Whether they are the cores of former volcanoes or mere eruptive bosses, it would be difficult to say, though I am inclined to regard them as the former. Votovorona and Iakiana (or Ihankiana ?) are probably the highest of these cones, though even these are of no great height. Votovorona is 350 feet high, and has been protruded through granite. The rock is of the nature of diorite, being composed of felspar and green hornblende. The angle of its slope is over 50°. About twenty or twenty-five miles N.N.E. of Ankaratra, and some seven or eight miles W.S.W. of Antananarivo, there is another of these probably eruptive bosses. It is a low conical knob of, perhaps, 150 or 200 feet high, and is also known by the name of Votovorona. There seem to have been a few small outflows of lava from the hill, and it not improbably forms the core of an old volcano.

Between the mountains of Ankaratra and Vavavato there exists a

* Dr. Mullens's estimates exceed these by about 500 feet.

† Described by Dr. Hatch, p. 354.

subconical hill of columnar trachyte*; this is possibly the neck of an ancient volcano exposed by denudation of its former covering.

Newer Volcanic Series.

In addition to the above evidences of former volcanic activity in the region of Ankaratra, there are many scores of volcanic cones, which are probably of later origin than Ankaratra. These are situated in two localities especially, in Mandridrano, on the western side of Lake Itasy, and in the neighbourhood of Betafo, in Vakin' Ankaratra, the former being about sixty miles west, and the latter from eighty to ninety miles S.S.W., of the capital. Both localities are about 130 miles from the eastern coast of the island, and 150 from the western coast. It is hardly necessary to say that all these volcanoes are extinct, and that there are none in activity at the present time in any part of Madagascar†. On the west side of Lake Itasy the volcanic cones exist in great numbers, and these therefore shall be first described.

The extinct volcanoes of this district of Mandridrano extend for a distance of about twenty miles north and south, and perhaps three or four east and west. They are, for the most part, scoria-cones. The cones are thickly studded over the district, in some parts clustering together more thickly than in others. Occasionally there is a series of cones which have evidently been heaped up by the simultaneous ejection of scoriæ from different vents situated on the same line of fissure, but so that the cones have run one into the other, leaving a ridge, generally curvilinear, at the summit. None of these extinct volcanoes reach the height of 1000 feet. Kasige, which is probably the highest, I found by aneroid to be 863 feet above the plain ‡. This is a remarkably perfect and fresh-looking volcano, whose sides slope at an angle of 32° or 33°. The scoriæ on the sides have become sufficiently disintegrated to form a soil, on which is found a by no means scanty flora; for, among other plants growing here, I gathered an *Aloe* (*A. macroclada*), a *Clematis* (*C. trifida*), two or three composite herbs (*Senecio cochlearifolius*, *Helichrysum lycopodioides*, *Laggera alata*, &c.), some grasses (*Imperata*

* Described by Dr. Hatch, p. 354.

† Scrope, in his 'Volcanoes,' 2nd edition, p. 428, says of Madagascar:—"There is some reason to believe in the existence of active volcanic vents in this great island;" and Dr. Daubeny, in the 2nd edition of his 'Volcanoes,' p. 433, in referring to the islands on the eastern coast of Africa, says:—"The principal of these are the great island of Madagascar, the isle of Bourbon, and the Mauritius, the first of which has been too little explored to allow of my announcing with certainty anything respecting its physical structure;" and, in a note, he adds, "Madagascar is stated by Daubuisson to contain volcanoes, on the authority of Ebel ('Bau der Erde,' tom. ii. p. 289), who reports that in this island there is a volcano ejecting a stream of water to a sufficient height to be visible twenty leagues out at sea." It is needless to say that no such volcano exists. Dr. Daubeny continues, "Sir Roderick Murchison, Dec. 1827, exhibited at the Geological Society some specimens of a volcanic nature said to have come from this island, but the locality was not mentioned."

‡ For description of lava from Kasige see Dr. Hatch's paper, p. 351.

arundinacea, &c.), a species of *Indigofera*, and an orchid. On its top is an unbreached funnel-shaped crater, which measures, from the highest point of its rim, 243 feet in depth. Contiguous with Kasige, and adjoining its south side, though not so high, there is another volcano, Ambohimalala, and many others are to be seen near by.

One thing with regard to these volcanic piles soon strikes the observer, which is, that they are frequently higher on one side of the crater than on the other. The higher side varies from north to north-west and west. This is accounted for by the direction of the wind during the eruption, causing the ejected fragments to accumulate on the leeward side of the vent. Now we know that the south-east trades blow during the greater part of the year in Madagascar, hence the unequal development of the sides of the cones. The same thing may also be observed in the volcanic piles in the neighbourhood of Betafo.

A very large number of the cones have breached craters, whence lava has flowed in numerous streams and flooded the plains around. These streams and floods consist, in most instances, I believe, of black basaltic lava; a sheet of this lava, the mingled streams of which have flowed from Ambohimalala and some other vents, has covered the plain at the foot of Kasige to such an extent as almost to surround the mountain. Similar sheets are to be seen in other parts of the district, but they are so much alike, that a description of one will suffice for all. Amboditaimamo (or Ambohitritaimamo?) is a small volcano at the south-west end of Ifanja marsh, and at the northern confines of the volcanic district. It possesses a breached crater turned towards the east. From this has issued a stream of lava which, following the direction of the lowest level of the ground, has swept through a small valley, round the northern end of the mountain, and spread out at its west foot. This sheet of lava, which is excessively rough on the surface, occupies but a small area of some two or three square miles. It has been arrested in its flow in front by the form of the ground. It is cut through in one part by a stream (Ikotombolo) which, in some places, has worn a channel to the depth of 80 or 90 feet. Its surface, which is slightly cellular, is covered by hundreds of mammiform hillocks, which must have been formed during the cooling of the liquid mass. The hillocks are mostly from 20 to 30 feet high, and apparently are heaped up masses of lava, and not hollow blisters. The lava itself is black, heavy, and compact, being porphyritic with somewhat large crystals of augite. As yet it is scarcely decomposed sufficiently to form much of a soil, though grass and a few other plants grow on it abundantly.

A little to the south of Amboditaimamo there is another volcano, known by the name of Andrarivahy. It is situated on the summit of a ridge of hills—astride of it, so to speak—and from its crater there has been an outflow of what must have been very viscid lava; for though the sides of the volcano and the ridge of hills form an angle of from 30 to 40 degrees, the ejected matter has set or "gut-

tered" on the slope, only a small portion of it having reached the valley below. This ridge of hills, through which the volcanic orifice has been drilled, is composed entirely of gneiss; and, indeed, it may be here stated that the whole of these volcanoes, as is the case also with those about Betafo, presently to be mentioned, rest upon a platform of gneiss.

As to the nature of the volcanic rocks of the district, it may be said that these comprise basalt, andesite, trachyte, trachytic tuff, palagonite-tuff, and basaltic and trachytic conglomerate. Some of the trachytic rocks contain large crystals of glassy felspar. Pumice, obsidian, and pitchstone do not seem to be found anywhere.

In addition to the numerous scoria-cones, there may be seen here and there in the district some dozen or more other volcanoes, differing entirely in character from those which have been spoken of above. These are large bell-shaped hummocks of trachyte or andesite. They are without definite craters, though one or two of them have more or less conspicuous depressions on their summits, showing that eruptive action has not been altogether wanting. These hummocks are chiefly composed of a light-coloured compact rock. This rock, having originally had a highly viscid or pasty consistency, has accumulated and set immediately over the orifice through which it was extruded. Such hummocks are Ingolofotsy, Beteheza, Andranonatoha, Angavo, Ambasy, Isahadimy, Ambohibe, Lazaina, Antsahondra, Antsangarahara (?), &c. Ingolofotsy, situated to the north-west of Lake Itasy, is perhaps the most striking in appearance of these hummocks. It bears some resemblance to a bell or a Turkish fez, except that its sides are furrowed with water-channels, and its truncated summit is notched in a remarkable manner. Its height above the plain is 665 feet; the inclination of its sides averages probably 50°. Adjoining Ingolofotsy on the south-west is Beteheza, and further still Andranonatoha, the latter of which consists of andesite *, which has probably welled out from orifices on the same line of fissure from which Ingolofotsy was extruded. From Andranonatoha, which seems to be the highest of all the domes, the lava has flowed in thick masses, but has stopped apparently at the foot of the mountain. Angavo is another of these fez-shaped domes. One singular feature in this mountain is its numerous shallow water-channels, which, on the north side, make their way down from the summit in a surprisingly regular manner, giving the appearance of an open umbrella with numerous ribs. From one point of view I counted as many as thirty-four of these channels. It may be mentioned in passing that, in a valley at the west foot of Angavo, there is a small crater the lips of which are level with the surface of the ground. This may, perhaps, be accounted for by supposing that the ejected materials from this and other craters near have so accumulated as to raise the level of the valley between up to the rim of the crater, and so to obliterate the cone, probably never of any great height.

* See Dr Hatch's description of this andesite on p. 355.

It is hardly necessary to say that these extinct volcanoes of Mandridrano must have been in activity in comparatively recent times. Possibly they belong to the historic period, though, so far as I am aware, no tradition lingers with regard to their being in a state of eruption *. That they are, at any rate, of recent date is shown by the almost perfect state of preservation in which most of the cones are still found, and by the undecomposed (or slightly decomposed) character of the lava-streams that have issued from them. There have been no terrestrial disturbances or modifications of any magnitude since the days of their fiery energy; the conformation of hill and dale was the same then as now, for in every instance the lava-streams have adapted themselves to the form of the existing valleys.

Another feature worthy of mention in this volcanic district is the lakes and marshes which occupy many of the valleys. Itasy is the largest of the lakes, and Ifanja the largest of the marshes. Now, most of these lakes and marshes have been doubtless formed by the sinking in of certain portions of the district, a fact made evident by the two following circumstances:—(*a*) on the south side of Kasige the gneiss may be seen to take a sudden dip beneath the volcanic pile, showing that, as the matter has been discharged from below, there has been a settling down of the cone, a fact made further evident by the existence of a small sheet of water, known as Bobojojo, in the immediate vicinity. But (*b*) on the western side of Ifanja marsh there is a small pond known as Mandentika. In the time of King Andrianampoinimerina (*i. e.* before the year 1810) there was a headland, so the people say, projecting into this pond, upon which were situated two or three houses. On a certain unhappy day the foundations of this headland suddenly gave way, and down it sank with the houses and their occupants, only one of the latter escaping. From that time the pond has been appropriately termed Mandentika ("sinking"), but previous to the catastrophe it was known as Amparihimboahangy. There is no doubt about the truth of this story, as I have myself seen traces of the submerged headland and houses appearing just above the surface of the water. The natives of the place say that the sinking was caused by a *Fananimpitoloha*, a seven-headed mythical animal that is supposed to live beneath the water.

Ifanja marsh is some four or five miles from one end to the other, and perhaps a mile or more wide in its greatest width. It runs in a northerly and southerly direction, with its southern end bending round towards the west, at the foot of which is the volcano of Amboditaimamo mentioned above. The marsh forms a considerable depression below the surrounding country. At its south-eastern corner there are some hot springs, which are much resorted to by sick people.

* I was told by a native that near the village of Amboniriana, north of Angavo, and not far from Ingolofotsy, there is an emission of carbonic acid gas (?) (*fofona*), and that the people say that formerly fire was to be seen. The place is named "Afotrona" (*afo*, fire; *trona*, grunting, or hard breathing), and would probably be worth a visit.

Lake Itasy needs no lengthy description here. It covers ground, roughly speaking, to the extent of about twenty-five square miles. It may not improbably occupy an area of depression due to volcanic action *; but be this as it may, there is a cause at its outlet sufficient to account for its formation. Here, lying in the river-bed, are numerous blocks of gneiss, many of them blackened with a covering of oxide of iron; and beneath this gneiss lava may be seen. Several volcanoes cluster round the outlet; but there is one —an inconsiderable hill—situated on the southern margin of the outflowing river, just above the rapids. There, distinctly enough, may be seen a low and much-worn crater, with its breached side facing the outlet; and gneiss blocks may be traced from the bed of the river all up the hill-side to the crater. There has evidently been first an ejection of volcanic matter, followed probably by an explosion tearing up and flinging out fragments of the gneiss through which the vent was bored; hence the gneiss blocks are superimposed upon the lava. Thus the water has been ponded back. The river has now cut its way several feet through the barrier thus thrown across its course; and by this continual erosion at its outlet, and the accumulation of sediment and the growth of vegetation at its head, the lake is slowly, though surely, decreasing in extent year by year.

It may be mentioned that the river Lilia, which flows from the lake, passes for several miles over sheets of black lava, through which it has cut its way. At Ambohipolo there are three fine waterfalls fifty or sixty feet high, and on the north side of the river, immediately below the second fall, there is an exposed section of columnar basalt. By the river-side near here, too, may be seen at the foot of the basaltic cliff carbonate of lime, which has been dissolved out from the basalt and been deposited on the shingle, forming conglomerate.

A few miles south of Lake Itasy the volcanoes begin to disappear, though they do not entirely die out for a good distance southwards; indeed the volcanoes of Mandridrano and those of the Betafo valley seem to be more or less connected by intermediate ones. Between the two districts, it is true, there are but few volcanic cones of any size, but craters may be seen here and there. In Dr. Mullens's map of the Central Provinces of Madagascar several "volcanic hills" are shown somewhat to the west of a straight line drawn between the two districts; but these are not in actual existence.

* Mr. Johnson says, "I am told here that Itasy was once a huge swamp, and that its becoming a clear lake is within the knowledge, or perhaps the traditions, of the people" (Antananarivo Annual, No. I., 1875, p. 60). If this be really true, it can only be explained on the supposition that there has been a recent subsidence of what is now the bed of the lake, as in the case of Mandentika mentioned above.

Mr. Sibree says, "The natives say that the lake Itasy. . . . . was formed by a Vazimba chieftain, named Rapèto, damming up a river in the vicinity, and so the rice-fields of a neighbouring chief with whom he was at variance were flooded, and have ever since remained under water." ('The Great African Island,' p. 136.)

A good deal of what has been said respecting the volcanic district of Mandridrano also holds good in regard to that of the Betafo valley and neighbourhood, where, however, the volcanic cones are fewer, and where trachytic and andesitic domes do not appear to exist. The largest volcano in the Betafo valley is probably Iavoko; it has a larger crater than any to be found about Lake Itasy. From this volcano a large sheet of black lava * has issued, upon which are found in abundance various species of plants, notably a *Euphorbia* and a stonecrop (*Kitchingia*). Almost all the plants growing on this lava bed, however, are of a succulent character, and can dispense with soil, requiring merely a foothold. On the sides of Iavoko may be picked up fragments of what appear to be calcined gneiss, which have been torn from the sides of the vent in the passage upwards of the volcanic matter. On some of the cones numerous crystals of augite as large as marbles may be found among the volcanic *débris*. There is one volcano, Tritriva, near Betafo, which, inasmuch as it is different in character from any others mentioned above, deserves a few words. It is one of those volcanoes off which the summit has been blown by explosive action, leaving what is known as a crater-ring, which is now the site of a small lake. The lake is not more than 100 or 200 feet in diameter, perhaps not so much as that; but there is reason to suppose that it is of great depth. The inner sides are steep for the greater part of the circumference, but on one side the lake is easily accessible.

The largest crater-lake in these volcanic districts (for there is said to be one also to the east of Ingolofotsy) is probably Andraikiba, a mile or two to the west of Antsirabe, though even this is of comparatively small size. It is, perhaps, a quarter of a mile in diameter, and is level with the surrounding country.

The volcanoes of Mandridrano and Betafo are situated twenty or thirty miles to the west and south-west of Ankaratra, and, judging from the small amount of denudation they have undergone, came into existence after the volcanic energy of Ankaratra had spent itself.

To the east of Imerina, near Ambohidratrimo, on the outskirts of the large forest, I found a few years ago several small volcanic craters. These also seem to belong to the class of crater-rings or explosion-craters. Although fragments of volcanic matter have been ejected from them, they are not sufficient to form a cone; and the craters, none of which exceed 100 yards in diameter and thirty feet in depth, have been probably produced by a single explosion of the pent-up forces below. With the exception of scoriæ and lapilli, which are sparingly scattered about, there is no visible sign of volcanoes, and one comes to the very verge of the craters before being aware of their existence. Two of the largest craters consist of saucer-shaped depressions, but are rather elliptical than circular in form; the others consist mostly of small cavities, deep in proportion to their width. Several of the craters are occupied by

* For description of this lava see Dr. Hatch's paper, p. 346.

sheets of water, with rushes and other aquatic plants around their margins.

About 90 or 100 miles N.N.E. of Antananarivo, in the province of Antsihanaka, it is reported that there are small volcanic craters; but as nothing definite is known respecting them, we can at present do no more than merely note their existence.

In addition to the above it may be stated that in some parts of the interior of Madagascar (especially, perhaps, in the vicinity of the volcanic districts) there are to be found a goodly number of circular or oval depressions which are in reality miniature craters. These generally occur on the summit or near the summit of the low undulating hills so abundant in this part of the island. They might easily be mistaken for mere ponds (for they are almost always occupied by water or marsh), but on examination cellular basaltic lava may frequently be found on their margins. In these places volcanic action must have been of the faintest kind, consisting chiefly in the discharge of heated vapours.

The largest craters that I have seen in the island are at Antongodrahoja, about 120 miles N.N.W. of Antananarivo. These craters, which are in close proximity, occupy the north and north-west ends of the hill on which the village of Antongodrahoja stands, the remnants of their walls, in fact, forming two of its sides, the village being situated between them. There is, at present, no sign of volcanic cone, and only a small arc of the circumference of the original craters now remains. The cavity to the north is a sort of double crater, evidently due to a change in the position of the centre of eruption, so that one of the orifices has overlapped the other, the remaining arcs of the two crater-rims forming a rude resemblance to the figure **3**. The western volcano has been the largest, and, judging from the portion remaining, has probably been about three miles in diameter, though no exact measurements of it have been taken. The materials poured out from these volcanic vents are of a basaltic character*, and apparently outflows of lava and fragmentary discharges have succeeded each other. The basalt assumes a spheroidal character in some places, and is now much decayed. Geodes are abundant in some parts of the basalt. Just above the waterfall in the northern crater they may still be seen *in situ*, but where the rock has decayed they have fallen out, and may be picked up by thousands. The majority of them are solid, others are filled with earthy matter; others, so the natives say, contain water, like the enhydros of Brazil; and many are hollow, being in various stages of progress towards solidity. A few show beautiful agate-markings in cross section. Some, again, have whitish horizontal layers deposited against the side of the wall that has been lowest in position, showing that the silica has crystallized in a surplus of water. Many of these hollow geodes are remarkable for their beauty, being lined inside with sparkling quartz-crystals, some comparatively large and others minute. In many

* Dr. Hatch, in his paper, p. 348, describes a specimen of rock from one of these craters.

of the stones these quartz-crystals are all coated with almost microscopic crystals of the same or some other mineral, so that they look as if they had been frosted, or delicately powdered with fine white flour. The crystals of others assume a mamillated form, the mamillæ being covered with minute crystals. These generally present a delicate blue tint. When these stones are broken in two, the hemispheres appear like veritable fairy grottos. I have never found geodes in any other locality, but here they are extremely abundant.

Volcanoes are also recorded as existing on the south-east and on the north-west coast; but of these nothing more seems to be at present known than the bare fact of their existence. Basaltic protrusions, dykes, and sheets also occur in numerous localities throughout the island, bearing witness to the intense volcanic energy that has prevailed at a remote period in this part of the world.

From what has been said respecting the volcanoes of Madagascar it will be seen that they run in a direction more or less parallel to the dominant strike of the rocks, that is to say, from north to south, and hence are part of the chain of volcanoes which passes along the line of the Red Sea and the eastern coast of Africa, and which Prof. Judd would include in his "fourth and subordinate band."

Thermal Springs &c.

Besides the volcanic phenomena mentioned above, thermal springs occur in various localities in Madagascar. They are found to the west of Valalafotsy (east of Imerimandroso); at a place in the bed of the river Ikopa, about 45 or 50 miles north-west of the capital (at the south end of the hill of Ankadivato in Valalafotsy); also at a place a few miles further down the river; at the south-east corner of Ifanja marsh; a few miles to the south-west of Mahatsinjo (south-west of Itasy); at Andranomafana (at the north-west [?] foot of Vavavato mountain); at Faravato (to the south-west of Vavavato) in the Betafo valley, where at one place the hot water pours out in great quantity and at a temperature of 130° Fahr.

These seven thermal springs lie in a northerly and southerly direction, extending for about a hundred miles, and corresponding with the line of the Mandridrano and Betafo volcanoes (about long. 47°). They probably point to a line of fissure.

M. Roblet reports hot springs as occurring on the banks of the river Sahasarotra, fifteen miles from Vinaninony. At Antsirabe, about seventy miles south-west of Antananarivo, there is a hot spring, and from several points carbonic acid gas is emitted. Another spring exists at Andranomafana (east of Andovoranto) near the east coast. The Rev. W. D. Cowan also gives the following positions where hot springs occur:—East base of hills near River Inamorona (47° 38′ E. by 21° 10′ S.); north of River Matsiatra near Ivohibola (47° 18′ E. by 21° 16′ S.). It is reported that there is a spring of mineral oil somewhere to the north of Betafo; and the French, it is said, have worked similar springs at Ambava-

toby on the north-west coast. But these reports I have had no opportunity of verifying. Dr. G. W. Parker finds that *an examination* of the water from springs in the district of Antsirabe gives the following results :—

"On evaporation, one pint (20 oz.) of water from each spring yielded the following quantities of solid salts :—

Spring No. 1	yielded 40	grains of salts,	or 2·0	grains	to 1	oz.	of water.
" " 2	" 38	"	" " 1·9	"	1	"	"
" " 3	" 42	"	" " 2·1	"	1	"	"
" " 4	" 28	"	" " 1·4	"	1	"	"

All these springs contain the same ingredients, viz. lime, magnesia, soda, and potash, in combination with chlorine, iodine, sulphuric acid, and carbonic acid, with the addition of free carbonic acid gas."

At Antsirabe there is a deposit from one of these springs of carbonate of lime, which is occasionally used for building purposes in the capital. Bubbles of carbonic acid may be seen rising from the surface of the deposit, and at one point, where there is a small spring, a mass of calc-sinter has been formed which is 80 feet long by 15 feet high. But the deposit also exists in several of the valleys in the vicinity to an unknown depth. In one of the small valleys, where there is a discharge of carbonic acid gas, there may be seen the dead bodies of grasshoppers, &c., that had ventured too near the noxious element.

In one of the valleys in the vicinity of the crater-rings of Ambohidratrimo, spoken of above, there is a deposit of siliceous sinter. It appears in one or two places, scarcely rising above the surface of the ground, in a valley of rice-fields, and has been deposited by springs which have long since ceased to flow. The sinter is exceedingly hard and compact, and is used by the natives for fire-flints. They know it as *vatofangala.* In some portions of it numerous fossils of what appear to be a species of *Equisetum* are imbedded.

About twenty or thirty miles to the north of Ambatobe, in North Antsihanaka, at a place named Analaroamaso, there is a considerable deposit of siliceous sinter, which contains particles of sand and pebbles imbedded in it. Ten or twelve miles further north, again, there is a second deposit of a similar character. Here there is also a circular shallow basin seventy or eighty feet in diameter, with a ledge of sinter round it. This is probably the site of an extinct geyser. These sinter-deposits are in the bed of the ancient lake described above, and, with the miniature craters that occur here and there, are proofs of recent volcanic activity. There is also a small deposit of siliceous sinter a little to the east of Andranomafana (between the capital and the east coast), where also there is much basalt.

Earthquakes.

So little is known respecting earthquake-phenomena in Madagascar, no scientific observations ever having been instituted, that it is scarcely worth while to refer to the subject. However, it may be

stated that hardly a year passes without one or more shocks being experienced in the central parts of the island, though they are never severe or of long duration; and the destruction caused by these earth-waves in some parts of the world is entirely unknown here*. The natives strangely imagine that earthquakes are caused by a whale (*trozona*) turning on its back.

Sedimentary Rocks.

So far as is known, not taking account of recent superficial accumulations, there are but few, if any, strictly sedimentary rocks intermingled with any part of the crystalline series. Possibly, however, there may be found here and there on the eastern side of the island rocks of Tertiary age; but sedimentary rocks do not "form a belt around the island," as Mr. Wallace, in his 'Island Life,' affirms. These rocks are found to the west and the extreme north and south of the island. My own observations with regard to these sedimentary strata, which, however, have been confined to the north-west of the country, confirm, with certain qualifications, the statement in the 'Bulletin de la Société de Géologie' (Aug. 1871, p. 88):—"Le savant voyageur a constaté que la grande île semble formée d'un noyau micaschisteux qu'entoure à l'ouest et au sud une vaste zone de formation jurassique. . . . . Cette zone, qui supporte une bande étroite de terrain nummulitique parfaitement caractérisé par des *Neritina Schmideliana* et pétri de foraminifères (appartenant aux genres *Alveolina*, *Orbitoides*, *Triloculina*, &c.), s'étend du bord sud de la baie de Narendry au versant ouest des montagnes granitiques, auxquelles est adossé le fort Dauphin. Elle est formée, comme on sait, de plaines coupées dans leur longueur par trois chaînes de montagnes qui courent du nord au sud." In a journey which I took to the north-west coast in 1886 I found, in various localities, a large number of fossils, which have been identified by Mr. R. B. Newton, F.G.S., of the British Museum, and of which a list is given in the Appendix (p. 331). These fossils belong to the Jurassic, Cretaceous, and Eocene systems. The accompanying map (Pl. XIII.) gives the exact localities where they were found.

In the north-west of the island sandstone is by far the commonest rock, covering vast stretches of country in thick beds. It varies much, of course, in texture and composition, from coarse grit, which is found adjoining the elevated region of crystalline rocks, to rocks of a fine grain. It is mostly of a reddish colour, but yellow and white calcareous sandstone is also common. It seems, so far as I could discover, to be unfossiliferous. Some of the mountains (which are comparatively few) composed of sandstone are quite remarkable in appearance, especially Angoraony, to the south-east of Anorontsanga, which is an isolated hill standing out as a witness to the

* In the year 1887 there were at least five shocks felt in the capital, being an unusual number. They occurred on Feb. 7 and 8, April 11 and 13, and May 20. One of these (that on Feb. 7) was the severest that has been known for many years, but was not sufficiently violent to do any damage.

enormous denudation to which the country has been subjected. It is composed of horizontal bands of sandstone weathered in such a way as to make it somewhat resemble a vast cathedral.

Beds of clay and shale are also common, many of which abound in *Belemnites* of various species. They contain also, in many places, large and numerous crystals of selenite. At the mountain of Tsitondroina, near Amberobe, cylindrical pieces of iron pyrites with a radiate structure may also be found. These, as well as species of *Belemnites*, are used by the natives as rifle-balls, and are known as *balahara* or *balanjirika*. In some places, too, in the clay (between Ankaraobato and Ankoala, for instance), large concretionary nodules of a calcareous nature are abundant; and to the north of Andranosamonta there are numerous septaria, the polygonal spaces being filled with calcite.

Extensive beds of limestone, which, as a rule, are abundantly fossiliferous, also exist in the north-west of the island. The limestone varies much in texture, composition, and colour; for instance, to the west of Ankaramy it is a black compact rock, and contains zinc-blende; in other places it is whitish and of close texture, or whitish and of friable texture. At Mojanga the rock is a greyish more or less compact dolomite. The limestone, in many places, presents a weathered surface of sharp-pointed and sharp-edged projections, which render it dangerous or impossible to walk on. In some localities, where exposed to the sea waves, it has the appearance of rude masonry. At Ambodimadiro, not far from Nosibe, the rock, a good section of which is exposed on the sea coast, is probably a kind of limestone-shale which easily breaks up into small rhomboidal fragments in the direction of its vertical joints, which run about 30° from a right angle one to the other. It contains numerous centipede-shaped markings of what are probably tracks or burrows of some animal, possibly worms. The rock is here also invaded by numerous dykes of amygdaloidal basalt *.

Near Ambalanjanakomby, to the north-west of Antongodrahoja, there is a deposit of lignite containing a large proportion of iron pyrites (or marcasite ?).

Coal has also been found in the north-west of the island. M. Guillemin, a French engineer sent out by the Company of Madagascar, reports that five coal-fields have been found, the coal from which he speaks of as *houille sèche*, *houille grasse*, and *houille à gaz*. The five outcrops of Bavatoby, and two others found in Ampasindava Bay, yield coal in small quantity near the surface, but are extremely rich at greater depths. The following is an analysis of the coal from Ambavatoby :—

Volatile matter	15·80
Carbon	70·87
Ash	13·33
	100·00

* Described by Dr. Hatch, p. 352.

The whole series of sedimentary strata above mentioned are remarkably horizontal, having perhaps generally only a dip of a few degrees seawards; consequently it is impossible to say upon what beds they are superimposed, except that at their eastern boundary they lie unconformably on the gneiss. Probably, however, future investigation may be able to discover the underlying strata—that is, the strata (if there are such) lying between the Jurassic and the crystalline rocks.

From what I have observed, the sandstone, clay, and limestone are arranged more or less in horizontal sequence from east to west; that is to say, the sandstone chiefly occupies the territory adjoining the crystalline rocks (being a sandstone-grit at the junction), the limestone forms the western zone, and the clay and shales are intermediate. Of course this rule may not hold good in every locality; but if this be the general sequence of the rocks, which undoubtedly it is, it becomes evident that their component materials have been derived from the elevated crystalline rocks of the interior, and that therefore these latter formed part, if not the whole, of the island previous to Jurassic times.

It may be worthy of mention that on the western bank of the River Betsiboka *, a few miles to the south of Mahabo (near Marohala), there is an outcrop of basalt with numerous agates.

In my journey to the north-west of the island in 1886 I came across some remarkable rocks which deserve notice. As I had not time sufficient properly to examine them or their surroundings, I can only give the data as I observed them from a hurried inspection of them, hoping that they may receive the careful attention of some future traveller. The rocks in question, which are crystalline, are located about a mile and a half to the north of Mahitsihazo (on the road between Andranosamonta and Ankaramy) in about 48° 5′ E. long. and 14° 22′ S. lat. One of the rocks is on the road near the summit of an ascent; it is most curiously, though irregularly, guttered with canoe-like channels, some of which are fully a yard in depth. It is as though it had been turned in a lathe, with ridges and prominences left between the parts gouged out, which parts, however, are not continuous round the stone. In the valley immediately to the south there is another of these curious rocks, and to the north there are several others, all of which are guttered in the same way. They do not seem to be protrusions from below, nor to belong to rocks disintegrated *in situ*, and there are no hills in the immediate neighbourhood from which they could have fallen, nor, indeed, is there to be found, so far as I know, any similar rock in the surrounding district. The gutters, in all that I saw, run in a direction round the rocks north and south, and the rocks themselves seem to observe the same direction in their distribution. I examined the rock upon which one of them was superimposed, and found it to consist of sand and clay. I would also point out for

* While speaking of the Betsiboka, I may say that within the last few years it has shifted its bed at Amparihibe. Formerly it ran on the west side of the village; now its course is about a mile to the east.

further investigation by future travellers some sandstone rocks a little further to the north: they seemed to me, from a very cursory examination, to be striated; but of this I am by no means certain.

It would be highly interesting to know whether there really are any signs of glacial action in Madagascar, and therefore I mention the above phenomena in the hope that they will receive further attention at some future time.

It may be as well here to give a list of the metamorphic and sedimentary strata of Madagascar, so far as they are at present known, referred to the European standard of geological chronology:—

Post-Tertiary .	Recent.	
Tertiary	Eocene.	
Secondary ...	Cretaceous ...	Upper.
		Neocomian.
	Jurassic	Oxfordian.
		Lower Oolite (Cornbrash, Bradford Clay, Fuller's earth).
		Lias.
Palæozoic ...	Silurian ?	
	Cambrian ?	
	Archæan.	

Economic Products.

Little is known with regard to the metals and industrial products of the island, as the native laws have hitherto prohibited mining of every description. It is now well known, however, that gold has recently been discovered in somewhat large quantity in certain localities, and, judging from the nature of the rocks, will doubtless be found in others when the country is opened up. The Government, which retains the monopoly of the precious metal, has recently been obtaining it from Mevatanana and Ampasiria, places about halfway between Antananarivo and Mojanga. Small quantities have also been obtained from the bed of a stream near Itompoananandrariny, in the west of Valalafotsy district, and also a few miles to the south of the capital, and perhaps in other localities as well. The gold is said to be of excellent quality; at present, however, the laws forbid both the search for it and the sale of it, although by no means all finds its way into the national treasury. Silver, as yet, does not seem to have been discovered. Galena is found abundantly somewhere in the neighbourhood of Ankaratra, and silver, it is said, is being extracted from it. The natives obtain their lead, which is used chiefly for bullets, principally, if not entirely, from this galena. Tin is said to occur in the district of Vakin' Ankaratra, but this requires verifying. Copper exists apparently in great quantity also in Vakin' Ankaratra. Iron is found, as has already been stated, in abundance as magnetite, also as hæmatite and ironstone. Sulphur occurs in beds near Antsirabe, in the neighbourhood of extinct volcanoes, and at Madera (?) to the north-west of Ankaratra. It is brought to Imerina, where (after being separated from its impuri-

ties by a rough process of sublimation) it is used in the manufacture of gunpowder. Nitre or saltpetre is obtained by lixiviating the soil (the decayed gneiss) and allowing the solution to crystallize. There is no special locality whence the nitre is obtained, though the natives say that certain soils, probably those rich in nitrogenous matter, yield it in greater abundance than others. Graphite and iron pyrites, as has been stated above, are found in various places. Mr. Ellis says that oxide of manganese has been found about 50 miles south of the capital. Lime is obtained from the deposit of travertine at Antsirabe, but as yet it seems only to have been employed in the erection of the Queen's palaces and a few other buildings. A beautiful variety of Amazon stone is found somewhere to the south of Lake Itasy. A kind of ferruginous clay (kaolinite) known as *tanimanga*, now much used for roofing-tiles, is obtained in many places, but it seems that it is not of very excellent quality, owing perhaps to the large proportion of iron present. Tourmaline (schorl and rubellite), corundum, sapphire, spinel, rutile, &c. are also found.

Lagoons.

Any paper dealing with the geology of Madagascar would be incomplete without a notice of the remarkable series of narrow lagoons which form so prominent a feature in the character of the east coast. I have no new facts to mention in regard to these lagoons, but their importance demands a word or two of description *. The lagoons are formed by the numerous rivers which flow from the mountains in the interior in their endeavour to discharge their waters into the Indian Ocean. They are found from 16° 52′ to 22° 25′ S. lat. It seems that there are more than twenty of these lagoons between the rivers Ivondrona and Matitanana (a distance of 300 miles), the total length of the isthmuses between them only amounting to $28\frac{1}{2}$ miles, or about one eleventh part of the whole distance. With a comparatively small outlay these lagoons might be turned into a continuous canal, which would be an immense boon to merchants and others resident in this part of the island.

Conclusions.

From what has been stated in the preceding pages, it will be seen that the eastern half of Madagascar must be classed as one of those extensive regions of crystalline rocks known as metamorphic. To what period of geological time, then, do the rocks of this region belong, and when were they elevated above the sea?

With our present imperfect knowledge of the country, these are questions more easily propounded than answered. As there are, so far as yet known, no rocks older than Jurassic resting upon them, we are left without one of the most valuable aids in helping us to determine their antiquity. The rocks, however, present the closest

* For particulars and maps see M. Grandidier's paper read before the Académie des Sciences.

resemblance to those of Archæan regions in other parts of the world. They consist of enormous bands of gneiss (with which granite is frequently associated), accompanied by beds of magnetic iron ore, hæmatite, mica-schist, clay-slate, quartzite, crystalline limestone, serpentine, hornblende-rock, graphite, &c. Indeed, throughout this extensive region all the rocks appear to belong to the crystalline series; they are, moreover, so far as is known, unfossiliferous, though what may await future discovery it is impossible to say. In the present state of our knowledge, therefore, of the geology of the eastern half of Madagascar, we can only say with certainty that the rocks of this region belong to the crystalline series, and that, judging from their close resemblance, in character and mode of occurrence, to the Archæan rocks of North America, Scandinavia, and the Scottish Highlands, they will probably hereafter prove to be Archæan. But with these there may not unlikely be found highly metamorphosed Cambrian and Silurian strata.

That this part of the island has been above the sea for an immense period is shown by the fact of its rocks having supplied the material which formed the extensive Jurassic, Cretaceous, and Eocene beds to the west, which lie on them unconformably, as also by the extensive denudation they have undergone. It may therefore confidently be said that the eastern half of the island has been dry land at least since early Mesozoic times. The forces which have elevated the island have probably been chiefly concentrated on the eastern side. This is shown by that side being much steeper than the western, and by the fact that the dominant dip of the rocks is towards the west. Further investigation will almost certainly reveal the existence of numerous faults running in a direction parallel with the east coast of the island. One of these faults not improbably exists at the western edge of the great Ankay and Antsihanaka plains, another immediately to the west of the capital, and another about long. 47°. If we may take the fringing coral-reefs *, which surround the island for the most part, as implying non-subsidence, and the absence of ancient sea-beaches or recent marine deposits

* Mr. Wallace, in his 'Island Life,' p. 386, says:—"We have also evidence that it [Madagascar] has recently been considerably larger; for along the east coast there is an extensive barrier coral-reef about 350 miles in length, and varying in distance from the land from a quarter of a mile to three or four miles. This is good proof of recent subsidence; while we have no record of raised coral rocks inland which would certainly mark any recent elevation, because fringing coral-reefs surround a considerable portion of the northern, eastern, and south-western coast." From this it would seem that both *barrier* and *fringing*-reefs are found on the east coast. But, if I am not greatly mistaken, these reefs are, at any rate for the most part, *fringing*-reefs. As for the raised coral rocks, there *are* such in the south-west of the island to the north of the river Onilahy, about twenty miles inland on the road to Manja; in fact they exist, it seems, throughout the southern part of the island. On some parts of the east coast the sea has recently but gradually receded several miles, but this seems to be owing to the heaping up of sand by the sea, aided by the wind, rather than to elevation of the land. Sand and pebbles thus left by the sea may be seen as far inland as the foot of Manjakandrianombana, some four or five miles west of Tamatave.

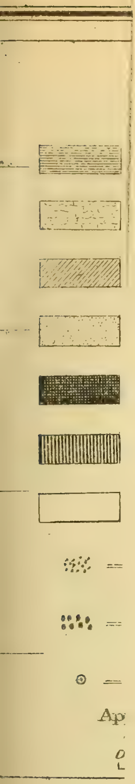
near the coast as implying non-elevation, we may conclude that the island generally is at present stationary. It appears, however, that the southern part of the country has undergone recent elevation. This is shown by the existence of extensive coral-beds, to the accumulation of which, M. Grandidier says, the southern part of the island seems to be due. Capt. Larsen says that raised beaches may be seen in certain parts of the south-west of the island, and Mr. Sibree informs me that he met with them to the south-east.

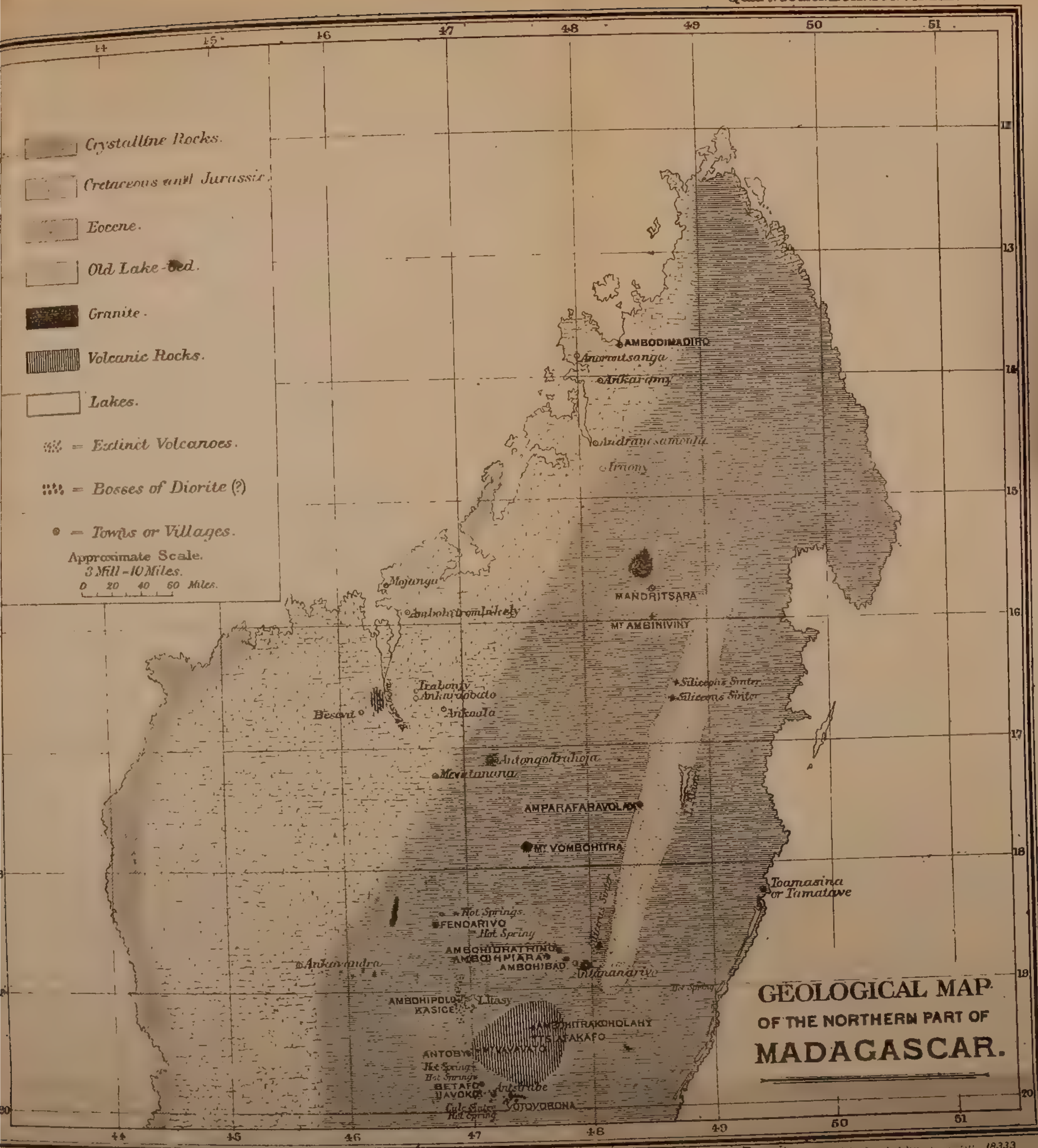
Another question of interest is, at what period, if ever, was there a land connexion between Madagascar and Africa? That the island once formed part of the mainland cannot well be doubted when we remember the relationship existing between the faunas, and the close affinity between the floras, of Madagascar and the adjacent continent. If we accept Mr. Wallace's theory as correct, that the character of the Madagascar fauna points to the separation of the island from the mainland previous to the migration into Africa from the Euro-Asiatic continent of the higher forms of mammals, then it follows that Madagascar became an island at least not subsequent to the later Pliocene period (for the migration probably took place in early Pliocene times, if not even in later Miocene), since which it must have remained isolated from the mainland until the present day, as the absence of such mammals proves *. Moreover, during a portion, at any rate, of Eocene (as also of Jurassic and Cretaceous) time, the western part of the island was beneath the sea, a fact shown by the presence of almost continuous nummulitic limestone on the west coast. From these considerations we may conclude that Madagascar was probably connected with Africa during some portion or portions or the whole of the time between the Eocene and at least the later Pliocene period † (allowing time for the migration of the mammals to Southern Africa, which would not unlikely keep pace with the gradual refrigeration of the northern hemisphere), after which the sea again divided it from the adjacent continent, and has kept it isolated to the present day.

In conclusion I have only to express my regret at the imperfect character of the present paper. It only professes to deal in a general way, as its title indicates, with a few of the more prominent features of the geology of Madagascar. Some of the statements made, it is not unlikely, when the region has been more thoroughly examined,

* That Madagascar has for a very long period been separated from the mainland is also proved by the character of its flora; for while about five-sixths of its genera of plants are found in other (chiefly tropical) countries, four-fifths (if not a larger proportion) of its species are peculiar to the island. This shows that a very lengthened period of isolation must have elapsed to have allowed of such a large amount of specific differentiation.

† This would seem to be confirmed by what we know respecting the Lemurs, the Centetidæ, and the Civets, which groups compose about five-sixths of the Madagascar Mammalia, and the ancestors of all of which existed in Europe in early Tertiary times. It must have been posterior to the Eocene but anterior at least to the Pliocene (or later Miocene) period (when the large animals were driven southward) that these lowly organized creatures spread as far as Madagascar, the existence of which in the island is unaccountable except on the theory of a former connexion with the mainland.





GEOLOGICAL MAP
OF THE NORTHERN PART OF
MADAGASCAR.

18333

will require to be modified, and perhaps some of the opinions expressed cancelled; and until the region is explored and surveyed by practical and competent men we cannot hope to see the geological structure of the country properly unravelled or its phenomena fully explained.

EXPLANATION OF PLATE XIII.

Geological Map of the Northern part of Madagascar.
(Scale about 80 miles=1 inch.)

APPENDIX.

NOTES *on* FOSSILS *from* MADAGASCAR, *with* DESCRIPTIONS *of two* NEW SPECIES *of* JURASSIC PELECYPODA *from that* ISLAND. By R. BULLEN NEWTON, Esq., F.G.S., British Museum (Natural History).

[PLATE XIV.]

THESE fossils were referred to me for determination by Dr. Woodward, F.R.S.

They are mostly in a bad state of preservation, many of them being merely casts. The collection, however, is important as forming nearly the first series of Malagasy fossils that have ever reached this country, and, on this account, we are considerably indebted to the collector, the Rev. Richard Baron, for having furnished us with material explaining the palæontological history of certain parts of Madagascar. The specimens, obtained from various localities in the north-west of the island, represent the Eocene, Cretaceous, and Jurassic formations. I have included in this Appendix a notice of a few fossils kindly lent me by the Rev. Dr. Deane of Edgbaston, which were collected several years ago in South-west Madagascar by the Rev. J. Richardson of Antananarivo. They consist of Jurassic specimens, three of which are in such good condition that I have had them figured, one being a new species of Pelecypoda, viz. *Sphæra madagascariensis*.

In drawing up this paper I wish to acknowledge assistance kindly rendered me by R. Etheridge, Esq., F.R.S.; G. C. Crick, Esq., F.G.S.; and C. D. Sherborn, Esq., F.G.S., in their respective subjects.

TERTIARY.

PISCES.

Some *Fish Otoliths* accompanying the collection were, I am informed, discovered on the surface of the ground at Ankoala, so, in all probability, they are of recent origin, though bodies similar to them in form and structure do occur in the Upper Eocene (Barton Beds) of Hampshire.

MOLLUSCA.

This group is represented by several internal casts of Gasteropoda

and Pelecypoda. These are not determinable; but they are of undoubted Eocene age, being associated with forms of Foraminifera belonging to that period.

Foraminifera.

These have been examined and identified by Prof. T. Rupert Jones, F.R.S., and include the following species:—

1. Alveolina oblonga, d'Orbigny, 1826. (Pl. XIV. figs. 18, 19.)

The specimen figured is partially imbedded in the matrix, though it is well preserved and of large size. The outer layer of the test is mostly removed, exhibiting the very fine and close transverse striæ which occur between the longitudinal flutings. This species is very abundant, and forms the chief feature of the limestone in this area.

Dimensions.—Length = 13 millim., maximum breadth = 8 millim.

Eocene (Paris; Bavaria; Egypt). North of Majamba Bay.

2. Nummulites sub-Beaumonti, de la Harpe, 1883.

Eocene (Switzerland). North of Majamba Bay.

3. Nummulites acutus, J. de C. Sowerby (sp.), 1840.

Eocene (India). North of Majamba Bay.

4. Nummulites obesus (Leymerie, MS.), d'Archiac & Haime, 1853.

Eocene (Southern Europe and Asia Minor). North of Majamba Bay.

5. Nummulites Beaumonti, d'Archiac & Haime, 1853.

Eocene (Switzerland; Palestine; Egypt; India). North of Majamba Bay.

6. Nummulites biaritzensis, d'Archiac & Haime, 1853. (Pl. XIV. fig. 17.)

The external covering of this specimen is partly removed, showing a fine natural dissection within. This fractured surface is also interesting as exhibiting five separate coatings in its structure.

Diameter = 12 millim., maximum thickness = 5 millim.

Eocene (Southern Europe; Asia Minor; Egypt; India; Java). North of Majamba Bay.

7. Nummulites Ramondi, Defrance, 1825.

Eocene (France, Germany, Hungary, Russia, Egypt, Arabia Petræa, Western Asia, India, &c.). North of Majamba Bay.

8. Assilina spira, de Poissy (sp.), 1805. (Pl. XIV. fig. 16.)

Diameter of specimen figured = 18 millim.; largest specimen collected = 22 millim.

Specimen imbedded in the rock, and "worn or dissolved down so

as to show the septa" (Prof. T. R. Jones). It is associated with *Nummulites Ramondi*, Defrance.

Eocene (Southern Europe and India). North of Majamba Bay.

9. ORBITOIDES, sp.
10. ORBITOLITES (?).
11. ROTALIA (?)

} Eocene. North of Majamba Bay.

CRETACEOUS.

CEPHALOPODA.

1. NAUTILUS FITTONI, Sharpe, 1853.

Upper Cretaceous (England and Germany). Two or three miles north of Ambohitrombikely.

2. BELEMNITES CONICUS, Blainville, 1827.

Neocomian (S. France). Ankaraobato.

3. BELEMNITES POLYGONALIS, Blainville, 1827. (Pl. XIV. figs. 3, 4.)

The laterally compressed form of this species serves to distinguish it from all other Belemnites. The alveolar cavity in our specimen is rather more elliptical than round, as is usually the case; but this may be due to weathering. The longitudinal impressions are distinct on both sides.

Neocomian (South of France). Ankaraobato.

4. BELEMNITES PISTILLIFORMIS, Blainville, 1827.

Neocomian (South of France). Beseva.

5. BELEMNITES BINERVIUS, Raspail, 1829.

Neocomian (S. of France). N.W. Madagascar.

PELECYPODA.

6. ALECTRYONIA (OSTREA) UNGULATA, Schlotheim (sp.), 1813. (Pl. XIV. fig. 12.)

There are several specimens to represent this very variable shell; but the specific character is unmistakable in all, that of the smooth median space which traverses the dorsal region of both valves.

Dimensions of specimen figured:—length = 65 millim.; width at expansion = 26 millim.; width at terminal part of shell = 13 millim.

Upper Cretaceous (Campanien) (England, France, Belgium, Russia, Spain, Algeria, Asia Minor, S. India, N. America, &c.). 2 or 3 miles north of Ambohitrombikely.

7. ALECTRYONIA (OSTREA) PECTINATA, Lamarck (sp.), 1806 and 1809. (= *Ostrea frons*, Parkinson, sp., 1811.)

Upper Cretaceous (Santonien) (England, France, Germany, Russia, Algeria). Beseva.

8. Alectryonia Deshayesi (?), Fischer, 1835.

Upper Cretaceous (Santonien) (France, Russia, Algeria, India). 2 or 3 miles north of Ambohitrombikely.

9. Gryphæa vesicularis, Lamarck (sp.), 1806 and 1809.

Upper Cretaceous (Campanien) (England, France, Russia, Spain, Asia, and America). 2 or 3 miles north of Ambohitrombikely.

10. Exogyra ratisbonensis, Schlotheim (sp.), 1813.

(= *Gryphæa columba*, Lamarck, 1819.)

Middle Cretaceous (Carentonien) (England, France, Germany, Russia, Spain, Asia). 2 or 3 miles north of Ambohitrombikely.

JURASSIC.

Cephalopoda.

1. Belemnites Sauvanausus, d'Orbigny, 1842.

Oxfordian (France). North of Andranosamonta.

2. Perisphinctes (Ammonites) polygyratus, Reinecke (sp.), 1818.

Oxfordian (England; Germany). North of Andranosamonta.

3. Stephanoceras (Ammonites) macrocephalum, Schlotheim (sp.), 1813.

Oxfordian (England; Germany; France). North of Andranosamonta.

4. Stephanoceras (Ammonites) Herveyi, J. Sowerby (sp.), 1818. (Pl. XIV. figs. 1, 2.)

This specimen agrees in all its characters with Sowerby's type. The inner volutions are distinct, though somewhat concealed within a deep umbilicus; the primary ribs bifurcate and pass over the back, where they meet the correspondiug primaries on the other side, with a free rib occasionally intervening. Height 37 millim.; width 33 millim.; diameter of umbilicus 11 millim. It may be remarked that this specimen bears a strong resemblance to *Ammonites Bainii*, Sharpe, from the secondary rocks of South Africa. (Trans. Geol. Soc. 1856, vol. vii. pl. xxiii. fig. 2, p. 197.)

Lower Oolite (England; France; Germany). S.W. Madagascar. Collected by the Rev. J. Richardson.

5. Stephanoceras (Ammonites) calloviense, J. Sowerby (sp.), 1815.

Callovian (Britain; N. of France; &c.). 5 or 6 miles south of Ankaramy.

Gasteropoda.

6. Nerita Buvignieri, Morris and Lycett, 1850. (Pl. XIV. fig. 5.)

The only difference between the Malagasy shell and this species, to which I have referred it, appears to be an absence of the decussations or transverse lines between the longitudinal ribs. In all other characters it agrees perfectly well.

Lower Oolite (Britain; France). Near Ankoala.

7. Nerinæa (allied to) Eudesii, Morris and Lycett, 1850.

Lower Oolite (Britain; France). S.W. Madagascar. Collected by the Rev. J. Richardson.

8. Nerinæa (allied to) Voltzii, Deslongchamps, 1842.

Lower Oolite (Britain; France). Near Ankoala.

9. Natica (allied to) intermedia, Morris and Lycett, 1850.

Lower Oolite (Britain; France). Iraony.

10. Natica (allied to) Verneuili, d'Archiac, 1843.

Lower Oolite (England; France). Iraony.

11. Natica (allied to) cincta, Phillips, 1829.

Lower Oolite (England; France). Iraony.

Pelecypoda.

12. Alectryonia (Ostrea) gregaria, J. Sowerby (sp.), 1815, *var.*

Lower Oolite (England; France; Germany). Near Ankoala.

13. Ostrea Sowerbyi, Morris and Lycett, 1853.

Lower Oolite (England; France). Near Iraony.

14. Perna mytiloides, Lamarck, 1819.

Lower Oolite (England; France; Germany). Iraony.

15. Pteroperna costatula, Deslongchamps (sp.), 1824.

Lower Oolite (England; France). Iraony.

16. Modiola imbricata, J. Sowerby, 1818.

Lower Oolite (England; Germany). 2 or 3 miles north of Ambohitrombikely.

17. Cypricardia rostrata, J. Sowerby (sp.), 1821.

Lower Oolite (England; Germany). 1 or 2 miles south of Ambohitrombikely.

18. Cypricardia (allied to) bathonica, d'Orbigny, 1850.

Lower Oolite (England; France). 2 or 3 miles north of Ambohitrombikely.

19. Pholadomya ambigua, J. Sowerby, 1819.
Lower Oolite (England; France). Iraony.

20. Ceromya concentrica, J. de C. Sowerby (sp.), 1825.
Lower Oolite (England; France). Iraony.

21. Opis (allied to) trigonalis, J. de C. Sowerby (sp.), 1824.
Lower Oolite (England; France). Iraony.

22. Lucina Bellona, d'Orbigny, 1849.
Lower Oolite (England; France). Iraony.

23. Myopsis dilatus, Phillips (sp.), 1829.
Lower Oolite (Britain). Iraony.

24. Astarte (allied to) angulata, Morris and Lycett, 1854.
Lower Oolite (Britain). Iraony.

25. Astarte (?) Baroni, n. sp. (Pl. XIV. figs. 9–11.)

Description.—Shell equivalve, very inequilateral, elongately ovate, thick, tumid; umbones contiguous and incurved; lunule small, oval; anterior sides short, posterior curved and sharply keeled, forming the boundaries to a deeply excavated escutcheon, which extends from the umbones to the posterior angle, measuring in its greatest width 9 millim.

Dimensions.—Length = 35 millim.; height = 29; breadth = 20.

This species resembles the *Cyprina boloniensis* of de Loriol (Mém. Soc. Phys. Genève, 1868, pl. v. figs. 9, 9*a*, p. 54), but differs from it in the greater length and width of the escutcheon-groove, which occupies the whole of the dorsal area of the shell; in de Loriol's specimen it extends to within 4 millim. of the posterior angle.

I have placed this species provisionally in the genus *Astarte*, as its dentition is unknown. Certainly it possesses external characters more in common with that genus than with *Cyprina*.

I propose to name this shell *Astarte* (?) *Baroni*, in honour of its discoverer, the Rev. Richard Baron.

Lower Oolite. Ankoala. Collected by the Rev. R. Baron.

26. Sphæra madagascariensis, n. sp. (Pl. XIV. figs. 6–8.)

Description (Right valve).—*Shell* equivalve, subequilateral, solid, ventricose; posterior dorsal and ventral margins rounded, anterior dorsal side oblique and deep; hinge-area massive and arched, containing two blunt principal teeth separated by a pit, the margin of which forms a slight lunular expansion beneath the umbo; posterior tooth transverse, the anterior one longitudinal, with a somewhat flattened upper surface; ligament-groove narrow, round and prominent; small pit-markings are present on the posterior lateral extremity of the hinge; surface ornamented with coarse concentric furrows.

Dimensions.—Length = 47 millim.; height = 47; breadth (for both valves) = 42 millim.

Observations.—The specimen under description consists of a right valve, the dentition of which agrees so closely with that of the *Sphæra* of James Sowerby that I have no hesitation in placing it under that genus. The specific distinctions are, however, sufficiently marked to separate it from the type form of *Sphæra corrugata*, found in the Neocomian beds of Sandown Bay, which has an almost straight hinge-line, with a massive flat expansion at each extremity, giving it a very quadrate appearance; it also possesses a deep pit situated beneath the posterior expansion of the hinge-area. The external surface has, in addition to the concentric furrows, close and transverse striæ producing a fimbriated character, which is not observable in the Malagasy specimen.

This new shell also differs considerably from the other species of *Sphæra* known to occur in the British and Foreign Oolites, chiefly on account of its large size and arched hinge-line.

Lower Oolite, South-west Madagascar. Collected by the Rev. J. Richardson.

Brachiopoda.

1. Terebratula maxillata, J. de C. Sowerby, 1823.

Lower Oolite (England; France). S.W. Madagascar. Collected by the Rev. J. Richardson.

2. Waldheimia perforata, Piette, 1856.

Lias (England; France; Germany). West of Ankaramy.

3. Rhynchonella (allied to) variabilis, Schlotheim (sp.), 1813.

Lower Oolite (Britain; France; Germany; Russia). Near Ankoala.

4. Rhynchonella (allied to) plicatella, J. de C. Sowerby (sp.), 1825.

Lower Oolite (Britain; France). Near Ankoala.

5. Rhynchonella (allied to) tetraëdra, J. Sowerby (sp.), 1815.

Lias (Britain; France; Germany). West of Ankaramy.

6. Rhynchonella obsoleta, J. Sowerby (sp.), 1815.

Lower Oolite (France; Germany). South-west Madagascar. Collected by the Rev. J. Richardson.

Echinodermata.

1. Pentacrinus (fragment of stem).

Lias? North of Andranosamonta.

2. Acrosalenia (fragments of test).

Lias? North of Andranosamonta.

3. STOMECHINUS (allied to) BIGRANULARIS, Lamarck (sp.), 1816. (Pl. XIV. figs. 13–15.)

The test of this specimen is more depressed than in the typical form, less pentagonal in shape, and the tubercles are rather more numerous. The mouth-opening is much injured and incomplete, and only one of the notches in the peristome is indistinctly preserved. The tubercles are raised on bosses surrounded by smooth areolæ, each areola being encircled by a series of granules. The base of the test is ornamented with well-developed tubercles, and is in contrast with the comparatively smooth appearance of the upper surface. The anal opening is large (5 millim. diameter), and surrounded by a series of granules which border a well-developed apical disc, the details of which are very clear and specific. The perforations of the oculars appear to be elongate in shape, in the genitals they are round. Two or three granules are also present on the ocular plates. The structure of the ambulacral and interambulacral areas is much the same as in the species to which I have referred this specimen; the poriferous zones are narrow, the pores being arranged in trigeminal pairs.

Dimensions.—Diameter = 37 millim.; height = 22.

Lower Oolite (England; France). South-west Madagascar. Collected by the Rev. J. Richardson.

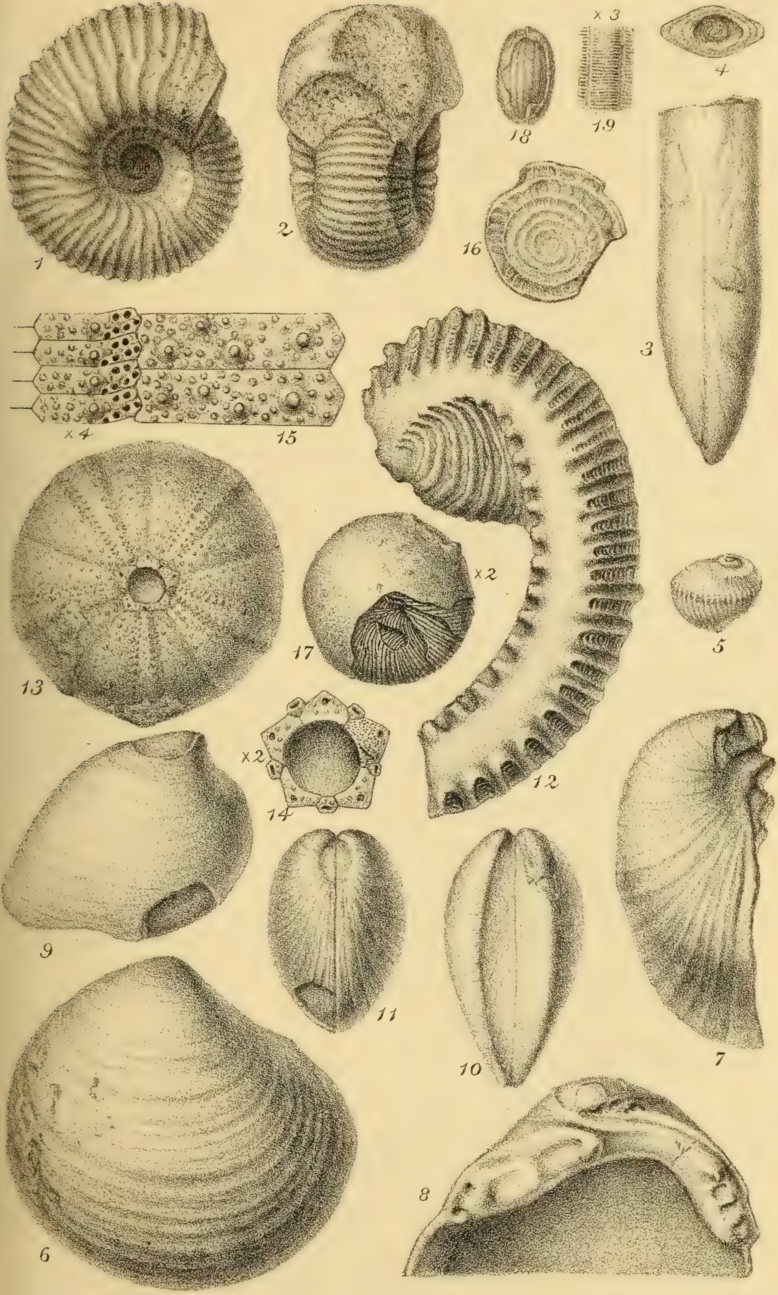
ACTINOZOA (Corals).

Isastræa and, probably, *Thamnastræa*, the structures of which are badly preserved and indistinct. The former may probably be *Isastræa Fischeri* (Fromentel, MS.), Fischer, 1873, Comptes Rendus, 1873, vol. 76, p. 113; but as the description of that species is unaccompanied by a figure, it is of little value.

Lias, five or six miles south of Ankaramy.

EXPLANATION OF PLATE XIV.

Figs. 1, 2. *Stephanoceras* (*Ammonites*) *Herveyi*, front and side views.
3, 4. *Belemnites polygonalis*, lateral view and transverse section.
5. *Nerita Buvignieri*, dorsal view.
6–8. *Sphæra madagascariensis* (n. sp.), exterior, interior, and profile views.
9. *Astarte* (?) *Baroni* (n. sp.), side view.
10. Ditto, posterior view, showing escutcheon.
11. Ditto, anterior view, showing lunule.
12. *Alectryonia* (*Ostrea*) *ungulata*, dorsal view of left valve.
13. *Stomechinus* (allied to) *bigranularis*, upper surface.
14. Ditto, apical disk. × 2.
15. Ditto, ambulacral and interambulacral plates, with poriferous zones. × 4.
16. *Assilina spira*.
17. *Nummulities biaritzensis*. × 2.
18. *Alveolina oblonga*.
19. Ditto, showing transverse striæ. × 3.



Berjeau & Highley del. et lith.

Hanhart imp.

FOSSILS FROM MADAGASCAR.

Discussion.

The President expressed the Society's obligation to Mr. Baron; a certain amount was known about the geology of the island, but the information was chiefly contributed by the French. He would be glad to hear if the crystalline rocks of Madagascar resembled those of the Seychelles. Might the beds at the base of the sandstone be representatives of the great Karoo formation? M. Fischer had described Jurassic fossils some years ago. Were any of the Lower Cretaceous fossils allied to the Neocomian fauna described by Krauss and Tate from S. Africa? It was possible that Mr. Wallace had exaggerated the similarity between the Malagasy and African faunas; the reptiles especially were very different. He inquired whether the flora showed any connexion with that of the other side of the Indian Ocean.

Dr. Geikie gave expression to the pleasure with which the Society had listened to Mr. Baron's paper, and hoped the Author would return encouraged to renew the researches which he had carried on with such industry and success in his distant home.

Mr. H. B. Woodward commented on the interesting discovery of so many species of common British fossils in the island; among these, *Ammonites macrocephalus* had been recorded also from India and Western Australia.

Mr. Topley referred to the intrusive bosses of granite, one of which had its porphyritic crystals arranged roughly parallel with the line of junction between the granite and the crystalline schists near the contact. The shape of the cones also was of great interest. He compared the structure of the volcanic district with that of Kilima-njaro.

The Rev. R. Baron, in reply, stated that the fossils described by Fischer were those discovered by Grandidier; they were included in the lists appended to the present paper. The sandstone was often red and apparently unfossiliferous; the recent fauna, as a whole, seemed largely allied to the African one; and the flora is distinctly allied to that of Africa, as he had shown in a paper read before the Linnean Society; there was also some connexion with the flora of India, the evidence for which was chiefly found near the east coast of the island. He did not think there was any connexion between the floras of Madagascar and Australia.

19. Notes *on the* Petrographical Characters *of some* Rocks *collected in* Madagascar *by the* Rev. R. Baron. By Frederick H. Hatch, Ph.D., F.G.S. (Read March 6, 1889.)

The rock-specimens here to be described were collected by the Rev. R. Baron during his extensive travels through Madagascar. They do not by any means represent the whole of his collection; but care has been taken to make the collection include all the more important types of crystalline and volcanic rocks.

The paper is divided into two parts, the first dealing with the older crystalline rocks, and the second with the comparatively recent volcanic eruptions.

I. THE OLDER CRYSTALLINE ROCKS.

The mountainous portion of Madagascar, extending from north to south through the eastern half of the island, is a ridge of old crystalline rocks, on the western flanks of which sedimentary formations have been deposited, and through which volcanic rocks have been erupted. Mr. Baron's collection comprises both foliated rocks (gneisses) and rocks in which there is no parallel structure visible in the hand-specimen (granite, gabbro or norite, pyroxene-granulite, and pyroxenite).

In the following pages the petrographical characters of these rocks will be described briefly, the order being as here given.

1. Gneiss.

Considered petrographically, the specimens of gneiss, collected by Mr. Baron, may be divided into an acid and a basic series, the former being characterized by the presence of abundant quartz with orthoclase as the dominant felspar, the latter by the subordination of the quartz and the predominance of plagioclase felspar.

a. *Acid Series* (*Granitite-Gneiss*).

To this division belongs a type of gneiss very common in Madagascar and occurring, for instance, in the immediate neighbourhood of the capital. It is a medium-grained rock with a granitoid texture, foliation not being very marked in the hand-specimen. The orthoclase presents a well-developed microperthite-structure, inclusions of triclinic felspar appearing in short oblong patches or in long narrow lamellæ, according to the direction of the section. Besides orthoclase, the rock usually contains a small quantity of triclinic felspar (oligoclase). White mica is completely absent. Black mica and deep olive-green hornblende occur in moderate quantity. The rock therefore has the composition of granitite,

and, adopting the method of nomenclature used by Mr. Teall *, I propose to call it *Granitite-gneiss*. Accessory constituents of this rock are iron-ore and zircon, the latter occurring in minute prisms imbedded in the felspar.

A very fine-grained light-coloured gneiss, belonging to this series, occurs near the mountains of Vombohitra, eighty miles north of the capital. In addition to orthoclase and plagioclase, this rock contains microcline, distinguishable by its characteristic reticulated structure.

Other specimens present a well-marked banded structure. A gneiss of this character occurs at a place to the north-east of Lake Itasy; it is composed of alternating light- and dark-coloured layers, the former consisting mainly of quartz and felspar (microcline, orthoclase, and a little oligoclase), the latter being rich in biotite. This rock contains apatite as an accessory constituent. Another banded rock occurs at the village of Ambohidratrimo, ten miles N.W. of the capital. Small red garnets occur in this rock.

b. *Basic Series* (*Tonalite-Gneiss*).

A dark-coloured gneiss, from Antoby, near the mountain Vavavato, seventy miles S.W. of the capital, may be taken as a type of this series. It is a well foliated rock, consisting of lenticular layers of black ferro-magnesian minerals alternating with thinner bands of quartz and a striated felspar.

Hornblende occurs in large plates and in small irregular flakes. Its pleochroism is as follows:—

α† = straw-yellow;
β = rich grass-green;
γ = bluish green.

$$\gamma > \beta > \alpha.$$

Maximum extinction-angle $= 15°$.

Associated with the hornblende is a uniaxial brown mica, occurring in thin plates. This mica is strongly pleochroic; rays vibrating parallel to α being pale yellow, those parallel to β and γ, blackish brown.

Magnetite and zircon occur as accessories.

The effects of mechanical metamorphism may be traced in this rock in a mosaic-like aggregation of granules of secondary quartz and felspar, surrounding the primary felspar-crystals, and contrasting with them by their greater freshness and pellucidity.

2. Granite.

The specimens of granite collected by Mr. Baron belong chiefly to the granitite type, that is to say, they contain only dark mica. Only one specimen (from the mountain Vombohitra, eighty miles N.

* Quart. Journ. Geol. Soc. vol. xliv. 1888, p. 314.
† Axes of elasticity.

of the capital, a boss protruding through gneiss) was found to be *granite with two micas.* This rock is a moderately coarse-grained aggregate of grey translucent quartz, pink orthoclase, microcline and oligoclase, together with a small quantity of muscovite and biotite, the latter altering to chlorite. Magnetic iron-ore occurs as an accessory constituent.

Granitites occur at the following localities :—a place from 10 to 15 miles N.N.W. of the town of Mandritsara (220 miles N. of the capital); near the mountain Votovorona, in the district Vakin' Ankaratra, immediately S.W. of the capital; and, as a dyke, near the village of Ambohipiara, 12 miles N.W. of the capital.

These are all medium-grained rocks, composed of pale grey quartz and reddish felspar, with interspersed lustrous plates of black mica.

With the aid of the microscope the following felspars were distinguished :—orthoclase, containing included patches and lamellæ of triclinic felspar (microperthite), microcline and oligoclase. The mica is a dark, small-angled variety, pleochroic in the following tints: α=pale yellow, β and γ=greenish brown to vandyke-brown. It is rich in inclusions, in the neighbourhood of which the pleochroism is much intensified ("pleochroic borders" or "halos"). Among such inclusions were observed granules of quartz, needles of apatite, sphene and minute crystals of zircon. Interesting as showing that mica is sometimes of later formation than both quartz and felspar is the fact that the former is sometimes found in allotriomorphic plates (in the rock from the first-mentioned locality) filling in the interspaces between these minerals, and retaining uniform optic orientation over considerable areas.

The specimen from Ambohipiara contains a green hornblende in addition to the mica (*hornblende-granitite*).

Sphene is the most abundant accessory constituent in these rocks. It occurs in rather large, slightly rounded grains of a pale brown colour, and contains included granules of felspar, proving that sphene (one of the earliest minerals produced in consolidation) was still separating from the magma when the felspar began to form.

3. Olivine-norite (*Rosenbusch*); Hyperite (*Törnebohm*).

This rock occurs, according to Mr. Baron, in large hills, protruding through the gneissose rocks on the north-east border of the plain of Antsihanaka, immediately north of the town of Amparafaravola, about 110 miles N.E. of the capital.

It is a dark-coloured rock of granitoid texture, remarkable, in the hand-specimen, for the vitreous lustre of its perfectly transparent felspar. It is composed of the following minerals :—plagioclase, hypersthene, olivine, brown hornblende, and green spinel.

The plagioclase occurs in allotriomorphic grains of varying size. It is twinned polysynthetically, on both albite- and pericline-types. The curvature of the twin-lamellæ, which is accompanied by an increase in the amount of striation and a marked "undulose"

extinction, is probably an effect of dynamic metamorphism. The extinction-angles indicate a basic felspar (labradorite or anorthite). Inclusions of gas and liquid are abundant; they are arranged along planes which intersect at varying angles and bear no apparent morphological relation to the enclosing crystal. Besides these inclusions, which are, comparatively speaking, large, there is also present in the felspar a fine dusty material which, under the highest powers, is incapable of distinct resolution and, under low powers, produces a slight turbidity. These minute bodies have every appearance of being original, and the enclosing felspar is perfectly fresh and unaltered. Similar dust-like inclusions in felspar have been described by numerous authors, recently by G. H. Williams * in the hypersthene-gabbro of Baltimore.

The pyroxene occurs in irregular masses, wedged in between the felspar-grains. Since it presents no crystalline contours, exact optical determination is impossible, but its properties are those characteristic of hypersthene. It possesses, for instance, the strongly marked pleochroism peculiar to this mineral (reddish brown to pale sea-green), and exhibits also, in places, an accumulation of thin brown plates, the orientation of which along definite crystallographic planes determines the metallic sheen which distinguishes the hypersthene of plutonic rocks from that occurring in volcanic lavas. In certain spots in the crystals the development of plate-like inclusions has been so great as to produce a fibrous appearance. In these places the pleochroism is also considerably intensified.

Brown hornblende is occasionally associated with the pyroxene. This mineral forms irregularly contoured masses, which present a well-developed prismatic cleavage and contain inclusions of iron-ore. Its pleochroism is strong, rays vibrating parallel to a being pale yellow, those parallel to β a rich reddish brown.

The olivine is quite fresh, with the exception that along the cleavage-cracks it is stained with hydrated oxide of iron. Some of the prisms are packed with granular and rod-like inclusions, showing a parallel arrangement. Occasionally the olivine-grains present a double zoning, the innermost layer being hypersthene, succeeded by a fringe of a pale green, fibrous hornblende (actinolite). Similar cases of zoning have been described by A. E. Törnebohm †, Frank D. Adams ‡, G. H. Williams §, and J. J. H. Teall ‖. G. H. Williams calls the zones "reactionary rims," and regards them as representing a reaction between the olivine and the felspar, while the latter was undergoing crystallization, the amphibole and pyroxene being intermediate products.

* The "Gabbros and associated Hornblende-rocks of Baltimore," Bull. U.S. Geol. Survey, No. 28, 1886, p. 21.

† "Ueber die wichtigeren Diabas- u. Gabbro-Gesteine Schwedens," Neues Jahrb. 1877, p. 383.

‡ "The Anorthosite Rocks of Canada," Brit. Assoc. Rep. March 1886, p. 666, also 'American Naturalist,' Nov. 1885, p. 1087.

§ "Peridotites near Peakskill, N.Y.," Amer. Journ. of Sci. (3) vol. xxxi. (1886) p. 35.

‖ British Petrography, p. 176.

Dark-coloured grains of irregular shape, having a metallic lustre in reflected light, but which are translucent with a deep green colour, belong to the spinel-group (pleonaste or hercynite).

4. PYROXENE-GRANULITE (*Lehmann*); TRAP-GRANULITE (*Naumann*).

Specimens of this rock were obtained by Mr. Baron from the village of Ambohibao, four or five miles N.W. of Antananarivo, where it occurs in masses in the gneiss. It is a dark-coloured crystalline and granular aggregate, in which glassy, striated felspar, red garnet, and a predominant jet-black material can be distinguished with the unaided eye. No parallel structure is visible in the hand-specimen. In both macroscopical and microscopical characters it is very similar to the pyroxene-granulites that occur in such abundance among the metamorphic rocks of Saxony *, Brittany †, and Sutherlandshire ‡. It is also related to the hypersthene-gabbros of Baltimore described by G. H. Williams §; these, however, contain no garnet. True pyroxene-granulites with garnet occur, however, according to Williams, at Claymont, Del., U.S.

Under the microscope the following minerals were detected:—plagioclase, pyroxene, hornblende, garnet, and iron-ore. These minerals form a holo-crystalline, granulitic aggregate, in which granules of one and the same mineral show a tendency to group together; in all cases the structure is allotriomorphic, the boundaries of each mineral being formed by those of its neighbours. The felspar is a plagioclase of ideal freshness and perfect clearness. It presents well-developed twin-striation (on both the albite- and the pericline-types) and high extinction-angles, and probably belongs to the labradorite series.

The predominating mineral is pyroxene. It occurs usually in rounded grains, which occasionally enclose lath-shaped portions of the felspar. It rarely presents crystalline contours. On rotation of the section over the polarizer the greater proportion of the grains are found to be strongly pleochroic (α and β=red tints; γ=pale green); but a considerable number remain of an unvarying grass-green colour. The latter are certainly a monoclinic pyroxene—omphacite or diallage; while there is very little doubt that the pleochroic mineral is hypersthene. It exactly resembles, for instance, the rhombic pyroxene of the Baltimore gabbros, which has been isolated and submitted to analysis by Williams ‖.

The hornblende is a dark-coloured, greenish-brown variety occurring in isolated, irregularly shaped grains. The pleochroism is as follows:—α=bright straw-yellow; β=dark greenish brown; γ=deep brownish green.

* E. Dathe, "Die Diallaggranulite der sächsischen Granulitformation," Zeitschr. d. deutschen geol. Ges., 1877, p. 274; J. Lehmann, "Die Entstehung der altkrystallinischen Schiefergesteine,' Bonn, 1884, p. 228.

† Ch. Barrois, "Les Pyroxénites des Iles du Morbihan," Ann. Soc. Géol. du Nord, xv. 1887, p. 69.

‡ "Recent Work of the Geol. Survey in the N.W. Highlands," Q. J. G. S. 1888, p. 388.

§ Bull. U.S. Geol. Survey, No. 28 (1886).

‖ *Loc. cit.*

The most striking constituent of the rock is the garnet. It occurs in irregular grains, which are of much greater size than the remaining minerals. In thin section they are pale pink; but in the hand-specimen they have a bright reddish-brown colour. Inclusions of pyroxene and iron-ore are not unfrequent; felspar also occurs, but rather more rarely.

5. Diallage-hypersthene-Rock (Pyroxenite, *Dana*).

Rocks of this composition occur in the valley at the eastern foot of the mountain of Ambiniviny, 200 miles N. of the capital, and at a place 20 miles S.E. of the village of Andranosamonta, N. Madagascar. They are finely granular and holocrystalline rocks and composed of green striated monoclinic pyroxene (diallage) and a strongly pleochroic rhombic pyroxene (hypersthene). By the addition of olivine these rocks would, and doubtless do, pass into peridotites and thence into picrites, norites, and gabbros. The name pyroxenite, first used by J. R. Dana *, who applied it to rocks very similar to the one described, is a very suitable designation for this type of rock. Barrois †, however, has used this name to designate rocks which he admits to be typical pyroxene-granulites, thus creating a needless redundancy in terminology. Dölter ‡, who also adopted the term pyroxenite for a variety of magma-basalt (viz. those without olivine), has since, at Rosenbusch's suggestion, abandoned it in favour of "augitite."

Pyroxenites (Dana), of the Madagascar type, occur as members of the Cortlandt series on the Hudson River, near Peekskill, N. Y. §. Williams also mentions their occurrence among the Baltimore rocks ‖; and of these he intends, I believe, soon to publish an account. Mr. Teall informs me that these interesting rocks are also found in the Gneissose series of the Highlands of Scotland.

II. THE VOLCANIC ROCKS.

The volcanic rocks here to be described have been erupted mainly from vents occurring in the older crystalline rocks. These vents are very abundant in the near neighbourhood of the high mountain of Ankaratra, which is itself of volcanic origin. For instance, in the region immediately to the west of Lake Itasy, at the western foot of the mountain, there are numerous extinct volcanoes, with craters, lava-streams, and all the usual accompaniments of intense volcanic

* "Geol. Relations of the Limestone Belts of Westchester Co., New York," Amer. Journ. Sci. (3) xx. (1880) p. 197.

† "Les Pyroxénites des Iles du Morbihan," Ann. Soc. Géol. du Nord, t. xv. (1887) p. 69.

‡ 'Die Vulcane der Capverden,' Graz, 1882, p. 137, and Neues Jahrb. 1883, i. p. 404.

§ "On the Norites of the 'Cortlandt Series' on the Hudson River, near Peekskill, N. Y.," Amer. Journ. Sci. (3) xxxiii. (1887) p. 194.

‖ "The Gabbros and associated Hornblende-rocks of Baltimore," Bull. U.S. Geol. Survey, No. 28 (1886), p. 55.

activity. Again, near Betafo, some 50 miles to the south of this district, there is a group of a dozen or more volcanoes. Volcanic rocks also occur sporadically as dykes, lava-flows, and dome-shaped hummocks in other parts of the island *. The greater proportion of the lavas are basaltic; but trachytes and andesites also occur. The basalts are here taken first.

1. Basalts.

They may be divided, according to their mineralogical composition, into the following groups:—

(*a*) Olivine-basalt.
(*b*) Olivine-basalt with hornblende and biotite in porphyritic crystals (hornblende-olivine-basalt).
(*c*) Olivine-free basalt with porphyritic hornblende (hornblende-basalt).
(*d*) Basalt with hornblende as a constituent of the ground-mass.
(*e*) Felspar-free basalt (magma-basalt, limburgite).

a. *Olivine-basalts.*

Basaltic lavas, rich in olivine, are of frequent occurrence among the volcanic rocks of Madagascar. The specimens, here described in detail, were collected at a lava-stream at the south foot of the volcano of Iavoko, the largest of the group of volcanoes in the neighbourhood of the village of Betafo, 80 or 90 miles S.S.W. of the capital.

This rock, which is slightly vesicular in the hand-specimen, is found, when examined with the microscope, to be composed mainly of a dark brown ground-mass, speckled over with innumerable minute granules of magnetic iron-ore, but containing granules of augite and olivine and, in lesser quantity, small needles of striated felspar. Unaltered glass does not appear to be present; for, under high powers, the brown interstitial matter is resolved into a plexus of colourless or faintly tinged microlites which, despite their minute size, show indications of double refraction.

Olivine and augite also occur in porphyritic crystals. Those of the first-named mineral are for the most part sharply contoured, sometimes giving six-sided sections (those in the zone (010), (001)). Finely marked cleavage-cracks parallel to (010) and (001) were observed. In some cases the interior of the crystals is filled with dark-coloured glassy material similar to the external base, with which it is usually connected by a narrow canal; detached inclusions of the same substance are also not unfrequent (figs. 1, 2). Some fine examples of interpenetration-twinning were observed (see figs. 3 and 4). The twinning-plane is (011) †. Fluidal movements in

* For full particulars as to the occurrence of the volcanic rocks, see Mr. Baron's paper.

† Kalkowsky, "Ueber Olivinzwillinge in Gesteinen," Zeitschr. für Krystall. und Min. 1888, x. p. 17.

the rock while in the molten condition are indicated by the presence of fractured crystals.

The augite, which, in thin sections, is of a pale purplish-brown colour, seldom occurs in well-shaped crystals. As in the "glomero-porphyritic" structure of Prof. Judd, the grains are frequently so aggregated as to entirely exclude the ground-mass. Here and there a more decided "centric structure" is produced by the

Fig. 1.—*Corroded Olivine with glass-inclusion.*

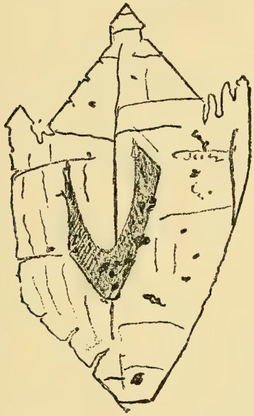


Fig. 2.—*Corroded Olivine with glass-inclusion.*

Fig. 3.—*Twin of Olivine.*

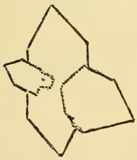
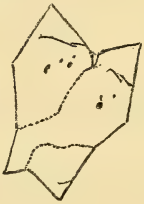


Fig. 4.—*Twin of Olivine.*



radiate grouping of augite-individuals around a central grain of olivine. Enclosed in the augite are abundant granules of magnetic iron-ore and glass. Less frequent are microlites of a colourless mineral (apatite).

Occurring sporadically are grains of quartz with liquid-inclusions. These grains have suffered considerable corrosion in the basic magma in which they floated; for their contours are rounded off, and they are surrounded by a narrow zone (what the Germans call a *Schmelz-zone*) of minute yellowish microlites (? augite), evidently produced by a change in the chemical composition of the magma.

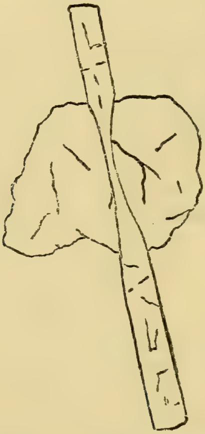
The sporadic occurrence of corroded grains of quartz in basalt has been noticed by several observers, who, as a rule, have regarded them as inclusions of foreign quartz taken up by the lava during its

eruption. J. S. Diller * and J. P. Iddings †, however, have recently argued against this notion. They consider them to be indigenous to the basalt, having separated at an early period in the rock's history, probably before its eruption and under conditions of pressure and "chemical equilibrium" at variance with those that obtain at the surface ‡. If this be so, the law of increasing acidity during consolidation cannot be universally true. With our present knowledge it is difficult to conceive olivine crystallizing out from a magma from which quartz has already separated §.

A very similar olivine-basalt, but without the quartz, forms the highest peak (Tsiafajavona) of the mountain of Ankaratra.

An olivine-basalt from Antongodrahoja, 120 miles N.N.W. of the capital, approximates to an andesitic type. The felspar is abundant and porphyritic, the crystals are of a prismatic habit, giving rectangular sections parallel to the long axis, and square cross-sections. As in the andesites, the felspars contain much included matter, glass and iron-ore. A pale-brown augite occurs in allotriomorphic grains, sometimes penetrated by a felspar lath (see fig. 5). Olivine is sub-

Fig. 5.—*Grain of Augite penetrated by a felspar-lath.*



ordinate. The ground-mass is a mesh of felspar-microlites, together with granules of augite, particles of iron-ore, and patches of interstitial glass (the "hyalopilitic" structure of Rosenbusch).

* "The Latest Volcanic Eruption in Northern California and its peculiar Lava," Amer. Journ. Sci. (3) xxxiii. 1887, p. 45.

† "On the Origin of Primary Quartz in Basalt," *ibid.* xxxvi. Sept. 1888, p. 208.

‡ Mr. Iddings suggests the influence of water-vapour at a great pressure.

§ In his latest work ('Theoretische Geologie,' p. 214) Dr. E. Reyer offers an ingenious explanation of this unnatural association. On account of its suggestiveness I give the passage in his own words:—"Ich vermute, dass es sich hier überhaupt nur um Grenzgebiete zwischen sauren und basischen Schlieren handelt, wo heterogene Associations-Kreise fortwährend einander begegnen. Tritt die Mischung erst kurze Zeit vor dem Erstarren ein, so kann natürlich jene absurde Association erhalten bleiben."

The doleritic type is also represented. Such a rock occurs, for instance, at Mojanga on the north-west coast of Madagascar. In this rock there is a marked ophitic structure, large allotriomorphic grains of augite being penetrated by prisms and microlites of felspar; the rock is nearly holocrystalline, glassy matter being present only in thin films between such felspar needles as are not enclosed in the augite.

A very curious rock, which, though diverging widely from the normal structure of the olivine basalts, may here be conveniently described, occurs three or four miles east of the village of Fenoarivo, in the district of Valalafotsy, 60 miles west of the capital.

It is a compact rock composed of augite, felspar, olivine, and magnetite.

The most abundant constituent is augite. This mineral occurs in small, sharply contoured, prismatic crystals of a pale brown colour. Under the microscope the crystals give lath-shaped sections with pyramidal terminations. Twinning parallel to (100) is frequent. In several cases it is polysynthetic, as in the triclinic felspars. The extinction-angle has a maximum value of about 42°.

These little crystals of augite are imbedded in a matrix of felspar. The latter presents no trace of twin-striation. In places it is slightly kaolinized. The relation between the felspar and augite may be said to be "ophitic;" but it differs from that structure, as represented in the dolerites, in that in the case under consideration the felspar is moulded upon idiomorphic crystals of augite, instead of augite upon felspar, as in the dolerites. Similar relations between felspar and augite have been described by Rosenbusch * in reference to vogesites, and by Teall † in certain Scotch traps.

The order of consolidation in the Madagascar rock appears to have been as follows:—

$$\text{1st phase} \begin{cases} \text{Magnetite.} \\ \text{Olivine.} \\ \text{Augite.} \end{cases} \qquad \text{2nd phase .. Felspar.}$$

b. *Olivine-Basalt with Hornblende and Biotite in Porphyritic Crystals.* (*Hornblende-olivine-basalt.*)

A rock of this composition occurs in the volcanic region west of Lake Itasy. Its predominant constituent is augite, occurring in large black crystals, imbedded in a slightly vesicular ground-mass, the latter being made up of microlites of felspar, granules of olivine, augite and iron-ore, together with a small quantity of interstitial glass.

Under the microscope the augite appears sometimes in irregular masses, sometimes in characteristic, octagonal sections, bounded by the faces (110, 100, 010). Included material is abundant, namely:—glass, magnetite, olivine, and, more rarely, a microlite of brown hornblende.

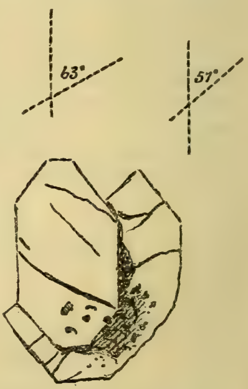
* Die massigen Gesteine, 1887, p. 316.
† British Petrography, 1888, pp. 188, 194, 214.

The crystals almost invariably show zonal structure, being composed of successive isomorphous layers, in which there is a gradually increasing difference in chemical composition, directly influencing the position of the axes of elasticity: the extinction between crossed nicols is consequently not uniform; it takes the form of a dark shadow, which on rotation of the section moves from the centre outwards towards the periphery. In one instance a difference of as much as 20° was measured between the peripheral layer and the central portion. Even in ordinary light a difference between the peripheral and central portions can sometimes be distinguished, the former being of a deeper tint than the latter. In sections parallel to the vertical axis the central portion often simulates the shape of an hour-glass (see fig. 6). This structure has been explained in the following way:—During the consolidation of the rock the augite first separates in skeleton-crystals of the shape of an hour-glass. Later on the depressions in the sides of these become filled in by augitic material of a slightly different composition and possessing, in consequence, an optical character deviating from that of the first-formed central portion. A curious instance of zoning in augite is shown in fig. 8. Twinning parallel to the orthopinacoid

Fig. 6.—*Hour-glass structure in Augite.*

Fig. 7.—*Augite with glass-inclusion.*

Fig. 8.—*Zoned Augite.*



is of frequent occurrence. In some cases this is polysynthetic, as in triclinic felspar (see fig. 9); in one case two twins are united along a common face (fig. 10).

Among the earliest minerals to separate were the hornblende and mica. Of these minerals, however, the major portion has undergone resorption into the molten magma during the later stages of consolidation. In some cases there remain small fragments, encircled by a broad zone of the products of fusion (*Schmelzzone*). In the case of the hornblende this secondary material usually retains perfectly the original form of the crystals after which it is pseudomorphous. It consists of: 1, opaque particles (magnetite); 2, doubly

refractive granules (augite); and 3, reddish-brown strongly pleochroic microlites (hornblende). Brown pleochroic microlites have been observed in the fusion-zones around hornblende by Werweke *, Sommerlad †, and Hyland ‡, all of whom agree in referring them to hornblende.

Fig. 9.—*Augite with twin-lamella.*

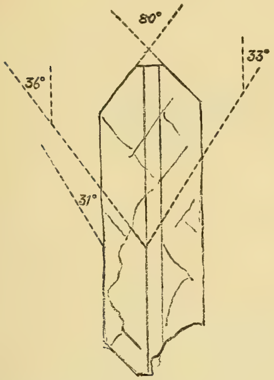
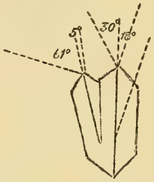


Fig. 10.
Twinned Augite.



The hornblende is of the common basaltic type (basaltine). It is strongly pleochroic in the following colours :—

$$\alpha = \text{pale straw-yellow.}$$
$$\gamma > \beta = \text{yellowish brown.}$$

The mica is a dark-coloured, strongly pleochroic variety (biotite).

c. *Olivine-free Basalt with Hornblende in Porphyritic Crystals.*

A lava-stream of the volcano Kasige, in the volcanic region to the west of Lake Itasy, has this composition: it is a black and finely vesicular rock composed of small porphyritic crystals of augite, hornblende, and apatite, imbedded in a brown ground-mass, which, besides glassy matter, contains abundant needles of striated felspar, microlites of augite, and minute granules of magnetic iron-ore. Under a high power the glass appears globulitic and, in places, fibrous, the latter appearance being due to the presence of numerous minute hair-like bodies (trichites).

Peculiar to this rock is the extraordinarily large amount of apatite. This mineral occurs in unusually fine large prisms, showing pyramidal terminations and giving hexagonal cross-sections. Longitudinal

* "Beitrag zur Kenntniss der Gesteine der Insel Palma," Neues Jahrb. 1879, p. 824.

† "Ueber hornblendeführende Basaltgesteine," Neues Jahrb. Beilage-Band ii. 1883, p. 139.

‡ "Ueber die Gesteine des Kilimandscharo und dessen Umgebung," Tschermak's 'Min. u. petr. Mith.' x. 1888, p. 236.

sections present the cross-jointing parallel to the basal plane and the central accumulation of inclusions in the direction of the vertical axis, characteristic for apatite. The mineralogical composition of the rock is that of an augite-andesite; but its structure is basaltic, the felspar being confined to the ground-mass, while the augite is porphyritic. With the exception of the absence of olivine it differs in no essential respect from the basalt described in section b.

d. *Basalt with Hornblende as a Constituent of the Ground-mass.*

The rock placed under this head is a basalt of rather unusual type. It occurs in one of a series of dykes on the sea-coast at Ambodimadiro, on the north-west coast. Originally vesicular, its cavities have become infilled with fibrous zeolites and calcite. The powdered rock effervesces strongly with hydrochloric acid; and on standing in the cold, gelatinous silica separates. No cubes of salt being formed in the solution when evaporated, the zeolites must be lime-zeolites (scolecite, phillipsite).

The chief porphyritic constituent of the rock is augite in numerous large and well-shaped crystals, which are partially invaded by serpentinous and calcareous alteration-products. Plagioclase also occurs porphyritically; but its crystals are few and small.

The ground-mass is a plexus of felspar-laths, between which are scattered numerous small crystals and needles of brown hornblende and granules of magnetic iron-ore. Interstitial glassy matter could not be detected.

In its general character the rock much resembles a tephrite; and an attempt was made to prove the presence of nepheline. But the fact that the hydrochloric-acid solution of the powdered rock gave no cubes of salt, tends to negative this supposition. After etching and treatment with fuchsine, however, a number of small specks retained the colour; and it is quite possible that these may be granules of nepheline.

It is an interesting fact with regard to this rock that, while augite appears as a porphyritic constituent, hornblende is present only in the ground-mass, thus reversing the usual order of things. The occurrence of hornblende as a constituent of the ground-mass of basalts has been mentioned by C. Chelius *.

e. *Felspar-free Basalt* (*Magma-basalt*, Bořický).

Belonging to this class is a black, compact, semi-vitreous rock, from a lava-stream near the village of Ambohipolo, in the volcanic region to the west of Lake Itasy.

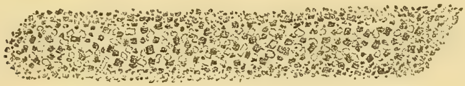
In thin section this rock appears as a clear brown glass, containing numerous microlites and crystals of augite and magnetite, the latter in square and lozenge-shaped sections, varying in diameter from ·006 mm. to ·086 mm. Olivine is rare. The augite is pale

* 'Erläuterungen zu Blatt Messel und Blatt Rossdorf der geolog. Karte des Grossh. Hessen.' Darmstadt, 1886. Rosenbusch, Die massigen Gest. vol. ii. p. 711.

yellow in colour. Its crystals are remarkably well contoured; they are bounded by faces out of the prismatic zone, terminated by a dome or hemipyramid.

Large pseudomorphs after hornblende occur sporadically. They are crowded with minute cubes of iron-ore, distributed uniformly through the crystal-section (see fig. 11). Between crossed nicols

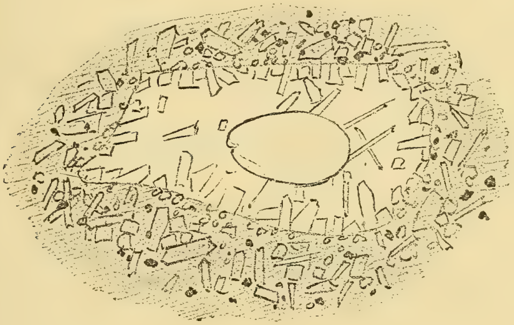
Fig. 11.—*Fused Hornblende-crystal recrystallized as Magnetite and Augite in Magma-basalt.* ($\times$70.)



they usually give aggregate-polarization. The polarizing substance resembles augite, probably produced by a melting-down of the hornblende substance.

A few grains of quartz, similar to those already described, are met with occasionally. The corroded grains are surrounded by a zone of colourless glass containing augite-microlites; this is succeeded by a second zone of brown glass, containing microlites and crystals of augite, together with granules of magnetite (see fig. 12).

Fig. 12.—*Quartz-grain melted down and surrounded by light and dark zones of Glass with Augite-microlites.*



The amount of glass increases in certain parts of the rock. The elongated shape of these more vitreous portions points to fluidal movements during the hardening of the rock. The central portions of these patches are often filled with a network of minute, opaque trichites, crossing one another at angles of 60°, 90°, and 120° (fig. 13).

Felspar-free basalts or magma-basalts (Bořický) have a wide-spread occurrence. They have been described, for instance, from the Kaiserstuhl (Rosenbusch), the Rhön and Vogelsberg (Bücking),

Bohemia (Bořický), Cape Verd (Dölter) and, quite recently, from Kilima-njaro (Hyland).

For those rich in olivine Rosenbusch has used the term limburgite; while the olivine-free type has been designated augitite by Dölter. The rock from Ambohipolo lies between the two, since olivine is present but in very small quantity. A type more nearly allied to the limburgites occurs near the mountain of Vavavato. This rock consists of a ground-mass composed of glass, augite, and magnetite, in which are imbedded numerous porphyritic crystals of perfectly fresh olivine.

Fig. 13.—*Trichites in brown Glass of Magma-basalt.* (×300.)

2. Trachytes and Andesites.

Trachytic rocks occur among the volcanic rocks of Madagascar; but they are not so well represented as the basalts in Mr. Baron's collection. Deserving of mention, however, are specimens of sanidine-trachyte from the top of Ambohitrakoholahy, a peak of Ankaratra.

This trachyte is a greyish-white rock, rather compact, but still rough to the touch. It contains porphyritic crystals of glassy sanidine imbedded in a ground-mass composed almost entirely of minute microlites of felspar, the arrangement of which in wavy lines imparts to it a marked fluxion-structure. Other constituents are very sparingly present: a few small crystals of hornblende and biotite, the original substance of which is almost completely replaced by opaque iron-ore; red specks of hæmatite and disseminated particles of iron-ore complete the list.

A columnar trachyte occurs at the south-west foot of Ankaratra. This rock differs from the preceding in the nature of the ground-mass, which, instead of being microlitic, is composed of minute, depolarizing particles (felspar) in cryptocrystalline aggregation. In this ground-mass are scattered isolated granules of magnetite and small prisms of green hornblende. Sanidine occurs in numerous por-

phyritic crystals. The presence of hornblende in the original magma is marked by pseudomorphs of iron-ore.

Andesitic lavas occur at Andranonatoha and on a hill in the volcanic region to the west of Lake Itasy. They are of a darker colour than the trachytes, namely, greyish brown. They contain striated felspar, which generally gives lath-shaped sections, but also occurs in large irregular masses, imbedded in a ground-mass composed of prisms of yellowish-green augite, granules of magnetite, and microlites of felspar. A glassy base does not appear to be present, unless it be as extremely thin films between the felspars of the ground-mass. Large porphyritic crystals of hornblende floated in the molten magma when it was first erupted: but they have been converted into granules of iron-ore; and only small fragments of the original hornblende-substance remain to mark its former presence.

To summarize briefly, we have found the older crystalline series of Madagascar, as represented by Mr. Baron's collection, to consist of foliated rocks (which are described as *granitite-gneiss* and *tonalite-gneiss*), and rocks in which no trace of foliation can be detected, comprising *granite*, *olivine-norite*, *pyroxene-granulite*, and *pyroxenite*. The majority of the granites are of the *granitite* type, but *true granite* (i. e. *granite with two micas*) also occurs. The basic members of the unfoliated series are interesting on account of their striking mineral combinations. The clear aspect and bright colouring of their constituent grains often make them objects of surpassing beauty when viewed under the microscope. Of deeper interest is the fact that these basic types, so well known in other areas of crystalline schists, —in Saxony, Brittany, Scandinavia, Scotland, and on the Hudson River—constitute in Madagascar, as at Kilama-njaro on the adjacent mainland, so large a part of the ancient floor on which the sedimentary rocks were laid down and through which the volcanic lavas were erupted.

The volcanic rocks consist mainly of *basaltic types*, only a few specimens of *trachyte* and *andesite* being represented in Mr. Baron's collection. The basalts vary, as regards composition, with respect to the presence or absence of quartz, olivine, porphyritic and microlitic hornblende, and biotite. One curious type contains idiomorphic crystals of hornblende as a constituent of the ground-mass. A felspar-free variety or *magma-basalt* is also represented. This rock contains only a small quantity of olivine, and is therefore intermediate in composition between the *limburgite* of Rosenbusch and the *augitite* of Dölter.

20. *On the* DENTITION *of* LEPIDOTUS MAXIMUS, *Wagner, as illustrated by* SPECIMENS *from the* KIMERIDGE CLAY *of* SHOTOVER HILL, *near* OXFORD. By ROBERT ETHERIDGE, Esq., F.R.S., F.G.S., *and* HENRY WILLETT, Esq., F.G.S. (Read January 23, 1889.)

[PLATE XV.]

THE specimens upon which this paper is founded were obtained by one of us (Mr. Henry Willett) from the Kimeridge Clay of Shotover Hill, and at no great distance from each other, although at different times—two in the spring and one in the autumn of 1887, and the fourth in the spring 1888. The size and perfection of these specimens are alone sufficient to warrant their being brought under the notice of the Society; but, besides this, one of them appears to represent a distinct species, probably new to England, if not also to the Kimeridgian fauna of France.

The species of *Lepidotus* known in England are as follows:—

Lepidotus fimbriatus, Ag.	Lias.
" *gigas*, Ag.	Lias.
" *pectinatus*, Egert.	Lias.
" *rugosus*, Ag.	Lias.
" *semiserratus*, Ag.	Lias.
" *tuberculatus*, Ag.	Great Oolite.
" *unguiculatus*, Ag.	Great Oolite.
" *macrochirus*, Egert.	Oxford Clay.
" *maximus*, Wagn.	Kimeridge Clay and Portland Rocks.
" *minor*, Ag.	Kimeridge Clay and Portland Rocks.
" *minor*, Ag.	Purbeck.
" *Mantelli*, Ag.	Wealden.
" *Fittoni*, Ag.	Wealden.
" *punctatus*, Egert.	Upper Chalk.

Section LEPTOGANOIDEI.

Suborder LEPIDOSTEOIDEI.

The Lepidosteoid Fishes range from the Permian to the present day. They are represented in the Permian rocks by the genus *Acentrophorus*. The following genera range through the British Secondary rocks:—

TRIAS: *Semionotus*, Ag.; *Saurichthys*, Ag.
LIAS: *Semionotus*, Ag.; *Lepidotus*, Ag.; *Dapedius*, Ag.; *Eugnathus*, Ag.; *Tetragonolepis*, Ag.; *Heterolepidotus*, Egert.; *Pholidophorus*, Ag.; *Pachycormus*, Ag.; *Ptycholepis*, Ag.; *Nothosomus*, Ag.; *Aspidorhynchus*, Ag.
GREAT OOLITE: *Mesodon*, Heck.; *Pycnodus*, Ag.; *Gyrodus*, Ag.; *Lepidotus*, Ag.
CORAL RAG: *Gyrodus*, Ag.; *Pycnodus*, Ag.
KIMERIDGE CLAY: *Gyrodus*, Ag.; *Pycnodus*, Ag.; *Lepidotus*, Ag.
PORTLAND OOLITE: *Pycnodus*, Ag.; *Ophiopsis*, Ag.; *Lepidotus*, Ag.

PURBECK BEDS: *Mesodon*, Heck.; *Pycnodus*, Ag.; *Cœlodus*, Heck.; *Microdon*, Ag.; *Lepidotus*, Ag.; *Pholidophorus*, Ag.; *Pleuropholis*, Egert.; *Histionotus*, Egert.; *Ophiopsis*, Ag.
WEALDEN: *Cœlodus*, Heck.; *Lepidotus*, Ag.
NEOCOMIAN: *Gyrodus*, Ag.; *Periodus*, Ag.; *Cœlodus*, Heck.
GAULT: *Pycnodus*, Ag.
U. GREENSAND: *Cœlodus*, Heck.
CHALK: *Gyrodus*, Ag.; *Acrotemnus*, Ag.; *Placodus*, Dixon; *Lepidotus*, Ag.
LONDON CLAY: *Pycnodus*, Ag.; *Gyrodus*, Ag.

Many species of *Lepidotus* attain a large size. *Lepidotus maximus*, Wagn. (=*Sphœrodus gigas*, Ag.), from the Lithographic Stone of Solenhofen in Bavaria, measures over 5 feet in length and 2 feet in depth of body; while *L. Mantelli*, Ag., from the Wealden Series (Hastings Sand) is nearly, if not quite, of equal dimensions.

The similarity of the teeth in *Sphœrodus* and in the larger species of *Lepidotus* (such as *L. maximus*) induced Agassiz to abolish the the latter genus (but with hesitation) in 1869. Prof. Owen, however, from the microscopic structure of the teeth, regarded the two genera as distinct. On the other hand, many continental palæontologists have rejected the genus *Sphœrodus* as being founded in error.

Lepidotus maximus, Wagn. (=*Sphœrodus gigas*, Ag.), has been found in the *Exogyra-virgula* stage of the Kimeridge Clay at both Shotover and Kimeridge, but hitherto only separate teeth have been recorded. Palatal and dentary teeth, equalling in perfection those described and figured by Pictet and Jaccard, and Sauvage, and illustrating so much of the dentition, have *never* previously been obtained in England.

The White Jura of Schnaitheim is remarkable for the identity of its fish-fauna with that of the Virgulian beds of the Neuchâtel Jura, and in both *L. maximus* occurs. Prof. John Phillips noticed *Sphœrodus gigas* (=*L. maximus*) as associated with *Exogyra virgula* and *Ostrea deltoidea* in the Kimeridge Clay of Shotover, in both the upper and lower zones of which the species has now been found.

Of the four specimens referred to in the present paper No. I. (in *two* pieces) comprises the upper dentition, which may belong to the same individual as No. IV. Under any circumstances the specimens belong to the same species. 18 teeth occur in the two fragments of No. I., the larger posterior portion containing five, and the smaller anterior one seven teeth, while the underside of the latter shows six teeth.

No. II. contains two teeth, an upper and a lower, belonging to the same species as No. IV.

No. III., probably the right dentary bone, appears to belong to a distinct species. It is remarkably perfect, and exhibits sixteen teeth, of which the successors of no fewer than six are exposed on the underside. The marginal series comprises the seven smallest teeth, those placed most inwardly being the largest. Compared with the dentary bone of those species of which that element is already known, the fossil approaches most closely to *Lepidotus maximus*,

Wagn.; but the bone is broader in proportion to its length, and the teeth are more numerous *.

No. IV. This corresponds undoubtedly to *Sphærodus gigas*, Ag. (*L. maximus*, Wagn.), so well described and figured by Pictet and Jaccard †. The dentition of this specimen does not, however, appear to belong to the left upper jaw, but to the dentary bone. Figs. 1 *c* and 1 *d* of pl. viii. of Pictet and Jaccard exhibit the successional teeth; and figs. 1 *a* and 1 *b* the upper and lower surfaces.

The upper surface of No. IV. (Pl. XV. fig. 1) contains 17 teeth, and the lower or successional series (fig. 2) consists of 15=32 in position. Pl. XV. fig. 3 shows a successional tooth in process of reversal.

EXPLANATION OF PLATE XV.

Fig. 1. *Lepidotus maximus*, Wagn., dentary bone, upper surface with 17 teeth.
2. The same, lower surface with 15 teeth.
3. Section through an upper and a lower or successional tooth, showing the reversal of the latter in progress.

All the figures of the natural size.

Discussion.

The President thanked Mr. Etheridge for bringing forward a species of such interest, and an addition to the fossil fauna of Great Britain.

Mr. Smith Woodward stated that we were able now to compare the British specimens with the Continental ones. Sir P. Egerton, about twenty years ago, supposed that he had teeth of the form described on a Pycnodont vomerine bone from the English Kimeridge Clay, and thus considered that *Sphærodus* had no relation with *Lepidotus*. It now appears that this determination was erroneous, and that the Continental view is correct.

Prof. Seeley mentioned that the teeth had long been among the commonest fossils from the Potton beds, and the succession of the teeth was first shown in those fossils, but the specimens were not comparable with those exhibited.

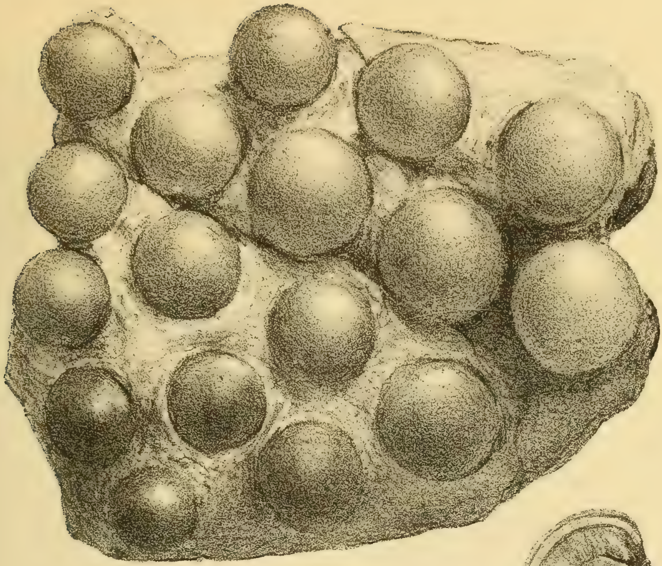
Mr. E. T. Newton spoke of specimens of *Lepidotus* from the Wealden, which also showed this remarkable reversal of the teeth, and thus indicated a close affinity between the Wealden *Lepidotus* and the Kimeridge Clay, so-called, *Sphærodus*.

Mr. Etheridge wished to record the indebtedness of the Society to Mr. Willett. He considered the Potton fossils *remaniés* from the Kimeridge Clay.

* See H. E. Sauvage, Mém. Soc. Géol. France, sér. 3, vol. i. pp. 1–17, pl. i. fig. 2.

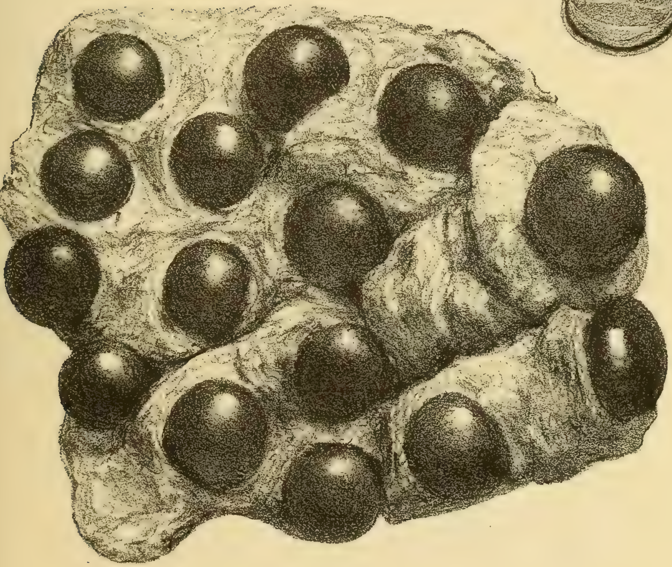
† Pal. Suisse, vol. for 1860, 'Reptiles et Poissons fossiles,' &c., pp. 35–41, pls. 8, 9, 4, pl. 18. 1.

1.



3.

2.



Ed. Michael del. et lith.

Mintern Bros. imp.

LEPIDOTUS MAXIMUS.

Kimeridge Clay, Oxfordshire.

21. *The* Basals *of* Eugeniacrinidæ. By F. A. Bather, Esq., B.A., F.G.S., of the British Museum (Natural History). (Read April 3, 1889.)

In the course of my paper on *Trigonocrinus* * I had occasion to refer to the views held by various writers as to the position of the basals in the Eugeniacrinidæ. As the question was then gone into thoroughly, and as the occasion is so recent, it is unnecessary to recapitulate the arguments there employed. Suffice it to say that I adopted the opinions of Prof. E. Beyrich † and Prof. K. von Zittel ‡ in preference to those of Mons. P. de Loriol § on the one hand, and of Dr. P. H. Carpenter || on the other. Dr. Carpenter, who was present at the reading of my paper, and joined in the discussion, was not wholly convinced by my arguments; at the same time he admitted that, if the specimens alluded to by Beyrich and v. Zittel showed the course of the axial canals to be as described by those authors, then I should be entirely justified in following their views as to the basals, anomalous though the said views appeared to him to be.

I had already spoken to Prof. v. Zittel on the subject and could not doubt the accuracy of his observations any more than his good faith. The sceptical attitude, however, maintained by Dr. Carpenter in all his discussions with me, both private and public, induced me to write to Prof. v. Zittel; for it should be remembered that neither Beyrich nor v. Zittel had ever described the actual specimens on which they based their conclusions, and that they had not given any figures or even diagrams. The only figure of importance in this connexion which I could find was that given by Goldfuss ¶; this,

* "*Trigonocrinus*, a new Genus of Crinoidea, from the 'Weisser Jura' of Bavaria," etc. Quart. Journ. Geol. Soc. vol. xlv. pp. 149–171, plate vi., Feb. 1889; see especially pp. 156–160.

† Zeitschr. deutsch. geol. Ges. xxi. p. 835 (Berlin, 1869).

‡ Handb. der Paläontologie, Paläozool. I. i. p. 385 (München, 1880).

§ Monogr. Crinoïdes Foss. de la Suisse, 3rd part, Abh. schweiz. pal. Ges. vi. pp. 196–97 (Geneva, 1879); and Paléont. Française; Invertébrés; Terrain Jurassique, xi. 1re partie, Crinoïdes, pp. 74–75 (Paris, 1882). [I was perhaps a little unjust to M. de Loriol in my previous paper. He has expressed his views more clearly in a letter, written on receipt of the Abstract of the present paper, under date 20 April, 1889. I am glad to be able to quote his remarks:—"L'organisation des canaux, si admirablement conservée dans les pièces de M. Zittel, témoigne évidemment qu'il y a en des pièces basales à une certaine phase de développement de l'*Eug. caryophyllatus.* Mais il est non moins certain qu'à l'état adulte il n'y a, dans cette espèce, aucune trace quelconque de basales. J'en ai examiné une assez grande quantité pour m'en convaincre; on n'en voit pas trace non plus dans aucune autre espèce. On peut donc dire avec vérité que les Eugéniacrines à l'état adulte sont dépourvus de pièces basales. Leur structure est telle qu'il n'y a aucune possibilité pour elles de se loger." April 25, 1889.]

|| "On the supposed Absence of Basals in the Eugeniacrinidæ," etc., Ann. & Mag. Nat. Hist. ser. 5, xi. pp. 327–334 (London, May 1883); and Report 'Challenger,' Zoology, vol. xi. part xxxii; Crinoidea, I. Stalked Crinoids, p. 227 (London, 1884).

¶ 'Petrefacta Germaniæ,' etc. (Dusseldorf, 1826–1833), pl. l. f. 3, *d.* Copied by F. A. Bather, "*Trigonocrinus,*" etc. *loc. cit.* pl. vi. f. 9.

however, though it favoured v. Zittel's view, did not agree with it at all points. Wishing to put the keystone to my argument, I therefore requested Prof. v. Zittel to send me some sketch or diagram, that I might publish it on his authority as an illustration to my paper. With a courteous generosity for which I cannot sufficiently thank him, he replied by sending, not only a further elucidation of his description, but also the specimens themselves. Owing to a mistake in the postal address, the specimens were in England for six weeks before they came into my hands; I was therefore unable to incorporate their evidence with my previous arguments. I should have thought it unnecessary to trouble the Society with any remarks of mine upon these specimens, had not circumstances abundantly proved the great need for a published figure with detailed description: for, be it remembered, science was acquainted with the bare conclusions of Beyrich and v. Zittel before de Loriol and Carpenter attacked the subject.

The specimens so kindly lent to me by Prof. v. Zittel consist of eight dorsal cups, more or less perfect, of *Eugeniacrinus caryophyllatus*, from the "Weisser Jura ϵ" (Quenstedt) of Engelhardtsberg, N. of Streitberg. The fossils are partially silicified, and weathering and acids have removed all portions not so preserved. Thus the external shell of each first radial, both inside and out and along the suture-line, remains like a box. The bounding surfaces of the canals which penetrated the once solid radials were equally exposed to the silicifying fluid: hence the canals remain as a system of branching tubes passing through the space of the now hollow radials *. In no specimen is the system quite intact; some of the best are represented in figures 1–4, and an accurate description of each specimen so figured is given in the explanation of the engravings (facing p. 362). From the various evidence of these specimens is reconstructed the perfect figure (fig. 5). It is thus seen that v. Zittel's account is absolutely correct. The axial canal of the stem passes up into the radial circlet, and gradually widens; at a short distance below the floor of the calycal cavity it gives off 5 interradial branches; these soon bifurcate, and the adjacent secondary branches converge. Before they meet, each secondary branch gives off towards the periphery of the dorsal cup a very short side-branch; this side-branch connects the secondary branch from which it springs with a ring-canal, which contained the interradial and intraradial commissures. From the level

* [*Note*, April 25, 1889. This mode of preservation is peculiar but not unique; a dorsal cup of *Millericrinus*, sp., in the British Museum (49210), said to come from Nattheim, shows the canals in the same way. Replacement of calcite by silica, though not impossible, is by some considered improbable. Results so nearly the same as to be undistinguishable might be obtained from the interpenetration of the reticular calcareous tissue of the Echinoderm skeleton by silica, and the subsequent removal of the calcite. The brilliant, opaque whiteness of the present specimens, and the texture of their surface, favours this explanation. Such a process can only have taken place soon after death, before any infiltration of calcite had taken place. The silica in the specimen of *Millericrinus* is, in places, distinctly crystalline; but this may be due to secondary changes.]

of this ring-canal the secondary branches continue to converge more slowly, and do not, as a rule, meet to form one radial canal until just before the upper articulating surface of the first radial is reached. This arrangement, of which the weathered specimens alone afford sufficient proof, has been confirmed by Prof. v. Zittel from the evidence of thin transverse sections.

The argument as to the position of the basals, founded on the evidence thus afforded, is as follows:—In every Crinoid in which the course of these canals has been traced, with the exception of *Bathycrinus*, the axial canal passes up into the basals, and there gives off five interradial canals; these interradial canals branch during their passage through the basals; the secondary branches pass into the radials, and there the adjacent secondary branches unite into radial canals. In *Bathycrinus* the interradial canals are likewise given off into the basals, and the only difference is that they pass some little distance up between the radials before diverging into secondary branches. The induction therefore is that the basals invariably contain the interradial canals, and, conversely, that the position of the interradial canals indicates that of the basals. In *Eugeniacrinus* the interradial canals originate in the middle of the radial circlet; we therefore infer that the basals have passed up between the radials, and as we can find no actual trace of them, we must suppose that they have been absorbed by the radials. Or perhaps, as Prof. v. Zittel writes in his letter of December 24, 1888:—"Die Basis muss somit durch Ueberwucherung der Radialia ganz nach oben gedrängt worden sein, und bildet wahrscheinlich im Grunde des Kelches eine kleine Rosette, wie bei *Antedon*."

To obviate certain difficulties which this view appears to some to present, it might possibly be argued that *Eugeniacrinus* is arranged on an extension of the *Bathycrinus* type. In other words, that the top stem-joint is, as Carpenter supposed, the homologue of the fused basal ring, and that the axial canal passes right through this, into the radials, before branching. This explanation would perhaps be more anomalous than the anomaly it explained; but, apart from that, the assumption has nothing to support it. On the contrary, in *Bathycrinus*, as in *Rhizocrinus*, which approaches it in this respect, there are no interradial commissures; the need for them seems to have vanished owing to the very high point at which the interradial canals branch; in fact the branches themselves act as commissures. But in *Eugeniacrinus* there is evidence of these interradial commissures; the ring-canal was complete; the arrangement was more primitive than that of *Bathycrinus*, and no argument from analogy can hold good.

If any recent form is to be compared with *Eugeniacrinus*, it must be *Holopus*; for the Holopodidæ are by all placed close to the Eugeniacrinidæ. Here unfortunately the evidence is incomplete; but, such as it is, it lends no countenance to the idea that the relation of the canals to the calyx follows the arrangement that obtains in the Bourgueticrinidæ. The extinct fossil Holopodidæ throw no further light on this question. At the same time such

forms as *Eudesicrinus* and the somewhat similar, though aberrant, *Plicatocrinus*, show how the basals may have gradually passed up into the hollowed aboral end of the radial circlet. A hollow of like nature is seen at the aboral end of the calyx in *Eugeniacrinus Moussoni*. These facts afford no positive proof as to the origin of the structure in *Eugeniacrinus*, but they render any comparison of the top stem-joint in *Eugeniacrinus* with the fused basals of *Holopus* valueless as an argument.

The structure above described for *Eugeniacrinus* is, according to v. Zittel *, also found in *Phyllocrinus* and, with the necessary modifications due to tetrasymmetry, in *Tetracrinus*.

The ideas which were thrown out in the concluding paragraph of my paper † have received strong support from the conclusions contemporaneously arrived at by Messrs. Wachsmuth and Springer ‡ in a most important paper, an author's copy of which reached me this morning (February 19th). While dropping altogether the distinction between Palæocrinoidea and Neocrinoidea, they are strongly inclined to refer *Holopus* among other recent genera to the Larviformia. With *Holopus* would naturally go *Eudesicrinus* and *Eugeniacrinus*.

Discussion.

The President observed that the Author's account of the valuable assistance given to him by Prof. von Zittel's kindness was peculiarly appropriate on the occasion of Prof. v. Zittel's election as a Foreign Member.

Mr. Percy Sladen remarked that the specimens exhibited by Mr. Bather were so remarkable, on account of the preservation of internal anatomy, that they cut away the ground from the opinions which he had previously held.

Dr. Hinde asked how the canals, which now appeared as silicified tubes traversing a hollow cavity, had been thus preserved.

The Author, in reply, stated that during life a canal, filled only with animal tissue, pierced each solid plate; the outer layer of calcite had been replaced by silica, and the inner portions subsequently removed by weathering and acids.

* Handb. d. Paläont. i. p. 386.

† *Loc. cit.* p. 167.

‡ "Discovery of the ventral structure of *Taxocrinus* and *Haplocrinus*, and consequent modifications in the Classification of the Crinoidea," Proc. Acad. Nat. Sci. Philad. vol. for 1888, pp. 337–363, pl. xviii. (Philadelphia, 1889).

[*To face* p. 362.

agrams of three recent crinoids showing the course of the
e plates. Drawn in the same position as fig. 5, for direct
plates are simply outlined, the canals are shaded.

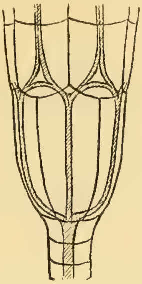


Fig. 7.

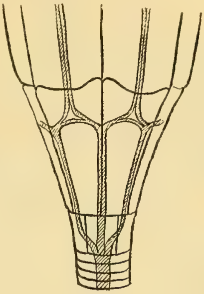


Fig. 8.

e normal type. 7. *Rhizocrinus*; no ring-canal. 8. *Bathycrinus*;
branches pass up between the first radials; no ring-canal.

)iagrammatic ground-plans of the usual pattern. The
he radials merely outlined, and the canals, where they pass
are in solid black.

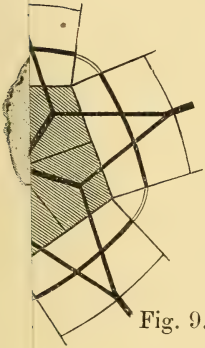


Fig. 9.

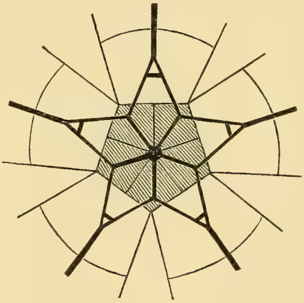


Fig. 10.

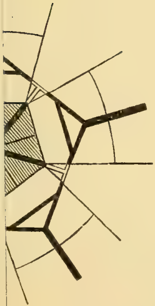


Fig. 11.

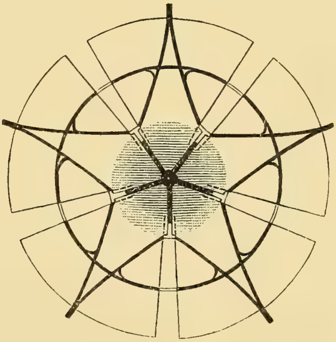


Fig. 12.

10. *Rhizocrinus*. 11. *Bathycrinus*. 12. *Eugeniacrinus*;
; here is of course theoretical, as the basals cannot be dis-
in the adult.

Figures 1–4. Drawings *ad naturam*, × 5 diameters, of specimens of *Eugeniacrinus caryophyllatus* from Engelhardtsberg.
Figure 5. Semidiagrammatic, × 10 diameters.

Fig. 1.

Fig. 2.

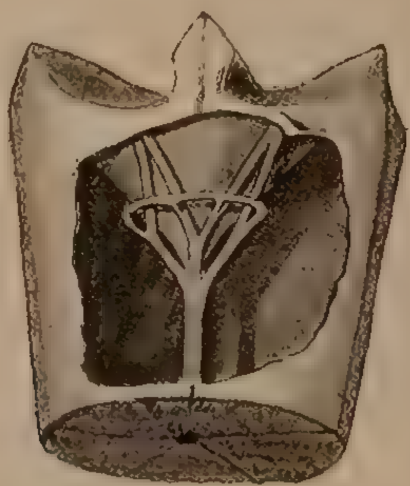


Fig. 5.

Fig. 3.

Fig. 4.

Fig. 1. The wall and bottom of the radials being partly broken away, the canals are seen thickly coated with silica. This specimen merely indicates that the axial canal does not branch till it enters the radial circlet.
2. Another specimen, seen from below. The five radial branches are seen, though obscured by silica; the lower part of the canals is broken away.
3. Portion of a dorsal cup from which two radials have been removed. The thin shell, which is all that remains of the once solid radial, is broken away on the right. Traces of the interradial branches are seen proceeding from the axial canal.
4. This specimen shows the canals very clearly, as it is not so much obscured by silica. The outer wall is drawn as more broken away than it is in the specimen. In addition to the interradial canals, secondary branches, and radial canals, this shows the short side branches and traces of the ring-canal. This latter is indicated by the spreading out of the side branches at their distal ends. The aboral end is uppermost in the figure.
5. A reconstructed figure, semidiagrammatic. The hollow shell of the radials is broken open and the internal structure disclosed. The ring-canal is moved rather more to the oral surface than it is in nature, so as to display the several branches.

Figures 6–8. Diagrams of three recent crinoids showing the course of the canals through the plates. Drawn in the same position as fig. 5, for direct comparison. The plates are simply outlined, the canals are shaded.

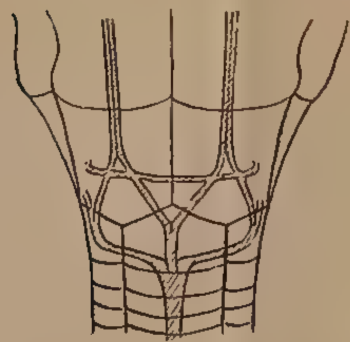


Fig. 6.

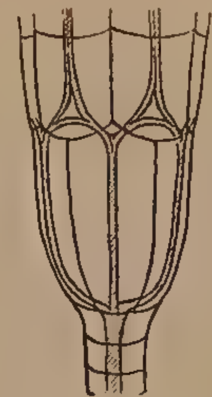


Fig. 7.

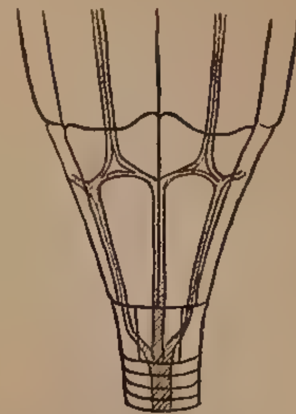


Fig. 8.

Fig. 6. *Pentacrinus*; the normal type. 7. *Rhizocrinus*; no ring-canal. 8. *Bathycrinus*; the interradial branches pass up between the first radials; no ring-canal.

Figures 9–12. Diagrammatic ground-plans of the usual pattern. The basals are shaded, the radials merely outlined, and the canals, where they pass through the plates, are in solid black.

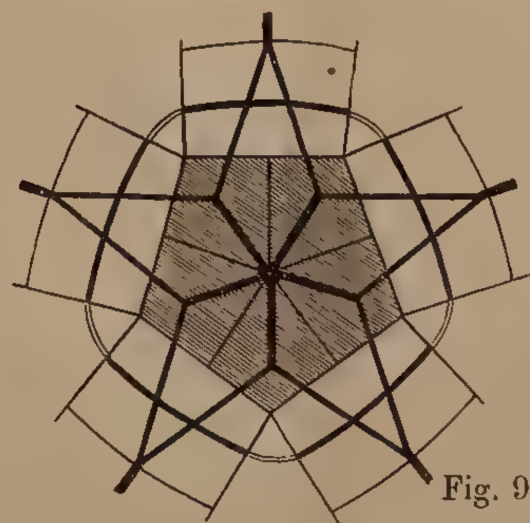


Fig. 9.

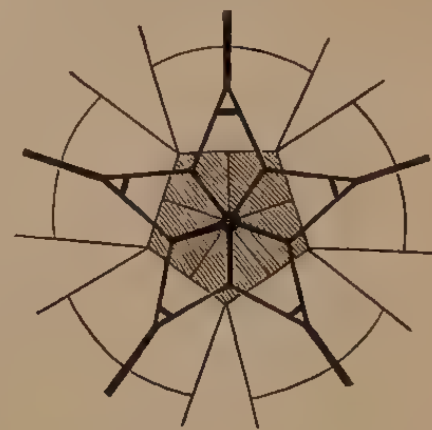


Fig. 10.

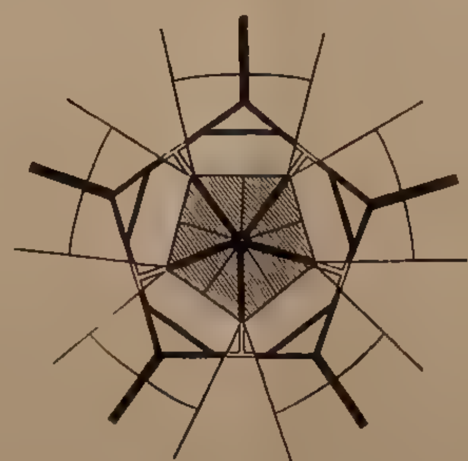


Fig. 11.

Fig. 12.

Fig. 9. *Pentacrinus*. 10. *Rhizocrinus*. 11. *Bathycrinus*. 12. *Eugeniacrinus*; the shading here is of course theoretical, as the basals cannot be distinguished in the adult.

22. *On the* ACTION *of* PURE WATER, *and of* WATER *saturated with* CARBONIC ACID GAS, *on the* MINERALS *of the* MICA FAMILY. By ALEXANDER JOHNSTONE, F.G.S., Assistant to the Professor of Geology and Mineralogy in the University of Edinburgh. (Read February 20, 1889.)

IN papers which have been published in the 'Transactions' of the Royal and Geological Societies of Edinburgh *, the Author has already given preliminary accounts of certain of his researches into the nature of the action of water saturated with carbonic acid gas on the following mineral and rock substances:—Orthoclase, oligoclase, labradorite, muscovite and biotite, hornblende, augite, olivine, steatite, magnetite, hæmatite, calcite, siderite, and statuary marble (crystalline limestone).

In the present communication he wishes to give some details of observations noted, and results of experiments carried out, while engaged in recent investigations into the nature of the changes produced by pure distilled water, and also by water saturated with carbonic acid, on the principal members of the mica family of minerals.

CLASSIFICATION OF THE MICAS.

It is convenient for all ordinary purposes to arrange the micas into two great classes. Division I. comprehends the varieties which are *anhydrous* or practically so; Division II. includes the micas which are most distinctly *hydrated*.

Division I.

In this section the micas generally known as muscovite (including lepidolite &c.) and biotite (including phlogopite and lepidomelane &c.) are placed. They are specially characterized by the possession of a splendent or shining lustre, and of a high degree of elasticity in their fine laminæ. Normal specimens of these varieties contain usually from about 1 to 1·9 per cent. of water, and none belonging properly to this division have more than 2·5 per cent. of that liquid in their composition. They pass, however, quite gradually, by the increase of water from 2·5 to 5 or 6 per cent., over into the next division, known as the hydromicas.

* "On the Action of Carbonic Acid Water on Minerals and Rocks," Transactions Edinburgh Geological Society, vol. v. p. 282. "On the Action of Carbonic Acid Water on Olivine," Proceedings Royal Society of Edinburgh, No. 127. "The Prolonged Action of Sea Water on Pure Natural Magnesium Silicates," Proceedings Royal Society of Edinburgh, No. 128.

Division II., *or Hydromicas.*

The micas assigned to this section are, in general appearance, quite similar to those of the first division, except that they show a less splendent degree, and a more pearly kind, of lustre, and are wanting in elasticity or at least have that property poorly developed. The fine laminæ are in many specimens somewhat talc-like in being tough and flexible, but in other cases are distinctly brittle, as can be proved by their quickly breaking to pieces when pressed between the finger and thumb. The "feel" is usually more or less greasy. The hardness and density are generally slightly less in this section than in Division I.

Margarodite, gilbertite, damourite, and sericite are mineralogists' names for varieties possessing the same composition as muscovite, differing from the latter mineral merely in containing at least about 5 per cent. of water. All of these varieties, it is evident enough, ought to be known under one term. The common name proposed for them by the Author is hydromuscovite.

Paragonite is a hydromuscovite with soda replacing part or all of the potash.

Voigite is the usual mineralogical name for a hydrous mica having the same composition as biotite, and which therefore the Author prefers to call hydrobiotite.

The minerals usually termed vermiculite and jeffreysite are other examples of hydrobiotites.

Fahlunite and the micaceous chlorites are related to the hydrobiotites.

In the Table on p. 365 the Author has attempted to give in a concise form his classification of micas.

Experimental and Observational.

Two pieces of muscovite, detached from a larger piece *, having, as ascertained by analysis, the chemical composition given below, were suspended, one in a wide-mouthed vessel containing two litres of *pure* distilled water, and the other in a like vessel containing two litres of distilled water *saturated with carbonic acid gas.* These two muscovite fragments, which were equal in weight, were allowed to hang completely immersed for a whole year (from October 1, 1887, to October 1, 1888) in their respective liquids. The liquids, which had an average temperature all the year round of about 60° Fahr., were gently agitated almost every alternate day during the period of immersion for about ten minutes at a time.

When the specimens at the end of the year were removed from their baths they were observed to have changed physically in much the same manner and to nearly the same extent. They had superficially dimmed considerably in lustre, had decreased slightly in hardness, and had lost a good deal of their original elasticity and

* Which was removed from the heart of a large compact mass of granite.

TABULAR CLASSIFICATION OF THE MICAS.

DIVISION I.	PASSAGE MICAS.	DIVISION II.
Practically Anhydrous Micas. Never contain more than 2·5 per cent. of water. Laminæ highly elastic.	Contain from 2·5 to 4 per cent. of water. Have *intermediate* physical characters.	Hydrous Micas. Contain at least 4 per cent. of water. Laminæ flexible or brittle.
A. MUSCOVITE, with its varieties:— Potash or ordinary muscovite. Soda muscovite. Lepidolite (including zinnwaldite and cryophyllite). Fuchsite.	A. MUSCOVITE, with its varieties.	A. HYDROMUSCOVITE, with its varieties:— Margarodite (including gilbertite, damourite, and sericite). Euphyllite. Paragonite (including pregrattite and cossaite). Œllacherite (contains baryta). &c., &c.
B. BIOTITE, with its varieties:— Ordinary or magnesia-iron biotite (including rubellane and anomite). Phlogopite or magnesia biotite (including aspidolite). Lepidomelane, or iron biotite. Astrophyllite (contains titanic oxide).	B. BIOTITE, with its varieties.	B. HYDROBIOTITE, with its varieties:— Voigtite. Vermiculite and jeffreysite &c. Pyrosclerite. &c., &c.

toughness. In fact their physical characters were now seen to be identical with those of some of the *natural* less hydrated varieties of hydromuscovite. The vessels in which the two specimens had been suspended were found to have on their bottoms a little fine mica-dust, which, by the action of the water, aided very likely by the atmospheric air, had been detached from the original solid masses during their twelve months' exposure to those fluids.

There was about the same quantity of this muscovite dust in the vessel which contained the pure distilled water as there was in the vessel which held the carbonated water. Besides the dust which had gathered on the bottoms of the vessels, numerous and very much finer mica-spangles were observed by means of the microscope to be suspended throughout the body of the fluids. Doubtless they were in the act of very slowly descending to the bottoms of the jars.

The waters in which the muscovites had lain were then separately and very carefully filtered again and again through several folds of the finest filter-paper, until no undissolved or suspended solid matter whatever remained in the liquids. Both the waters were then evaporated to dryness in different basins, and not a grain of solid residue was observed to be left behind in either case, showing that nothing had been removed from the muscovites *in a state of solution*, either by the pure water or by the water saturated with carbonic acid gas.

The two specimens of muscovite which had been thus experimented with were afterwards analyzed and their analyses compared with that of the mass to which they had originally belonged. These three analyses are given below: I. of fresh Muscovite, II. of Muscovite after lying in distilled water for a year, III. after a year's immersion in carbonic-acid water.

	I.	II.	III.
Silica	47·76	46·95	46·33
Alumina	35·13	34·45	34·86
Potash..........	9·91	9·62	9·85
Ferric Oxide	3·95	3·84	3·69
Magnesia........	0·80	0·77	0·83
Soda	trace.	trace.	trace.
Water	2·43	4·19	4·42
	99·98	99·82	99·98

It will be seen from the above analyses that all the chemical change effected in the muscovites by their twelvemonth's immersion was hydration, and that the hydrating process went on as readily in the pure water as in the water-solution of carbonic acid gas. In fact in both cases the specimens were equally rapidly converted into hydromuscovites.

Compare the analysis which is now given of one of the lower natural hydromuscovites with the analyses II. and III. above.

IV. Analysis of a Hydromuscovite (Margarodite). *Dana.*

Silica	46·50
Alumina	33·91
Potash	7·32
Ferric Oxide	2·69
Magnesia	0·90
Soda	2·70
Fluorine	0·82
Chlorine	0·31
Water	4·63
	99·78

Two pieces of biotite were in like manner exposed for a year to the action of water, pure and carbonated. Fine mica-dust, the minute flakes of which had the same general forms as those obtained from the muscovite, was also observed at the bottom of each of the vessels at the end of the period of immersion; but in this case that containing the carbonic-acid water appeared to have a distinctly larger amount of dust than the vessel filled with pure water. When the biotite-mica dust which had been formed by the action of the *pure* distilled water and air was examined, it was found that all the minute plates had become distinctly hydrated, had been, in fact, converted into hydrobiotites. No other change, physical or chemical, seemed to have taken place. The biotite dust, however, which had formed in the carbonic-acid water showed some important changes. The minute spangles had all become thoroughly hydrated as in the above case; but they had, besides, become considerably lighter in colour. Some of the more highly decolorized flakes, when examined by polarized light, now exhibited practically no pleochroism, whereas the very finest plates detached from the portion of the mineral which had not been exposed to the action of either of the waters were distinctly dichroic, as also were those which had lain in the pure distilled water only; so that the result of the prolonged action of the carbonated water on the minute biotite flakes detached from the suspended mass had been to convert them into ordinary hydromuscovites. Superficially, the suspended biotite masses were found, like the minute flakes, to have lessened in degree of lustre and slightly in hardness, to have lost considerably in toughness and elasticity, and to have acquired a more or less unctuous feel. The solid fragment of biotite which had been placed in the carbonated water likewise showed slight decoloration or bleaching on the edges of the superficial laminæ. The mass which had hung in the pure water showed no such change. An examination was next made of the liquids to the action of which the biotites had been subjected. Both were separately and very carefully filtered from their solid contents and evaporated to dryness in separate dishes. The pure distilled water passed off without leaving *any* residue, showing, as in the case of the muscovites, that the only chemical change resulting from its action on the biotite was that of hydration.

In the water of the other vessel, however, which was saturated with carbonic acid gas, distinct traces of the bases magnesia and iron were found in a state of solution, so that when the liquid was evaporated down the substances remained behind, as whitish carbonates *, to form a very small, but quite distinct, residue. The biotite which had been exposed to the action of the carbonated water had then, evidently, besides undergoing hydration, been chemically decomposed to a slight extent.

Here follow three analyses; the *first* (V.) of the original fresh biotite, the *second* (VI.) of the specimen of biotite which had been subjected to the action of the pure water, and the *third* (VII.) of the biotite which had been suspended in the carbonic-acid water:—

	V.	VI.	VII.
Silica	41·02	40·79	42·10
Alumina	17·99	16·81	19·45
Magnesia	20·04	18·90	17·35
Potash	9·35	7·99	8·14
Ferric Oxide	10·50	9·85	8·20
Soda .... } Manganese ...... }	traces.	traces.	traces.
Water	1·71	5·52	5·83
	100·61	99·86	101·07

The third analysis (VII.) shows a decided loss of magnesia and iron. It seems to the Author that if his experiments had run on for a score of years instead of one, even the suspended mass of biotite in the carbonated water would, at the end of that period, by the continued loss of magnesia and iron, have shown a decided resemblance, both chemically and physically, to any ordinary hydromuscovite. Possibly many of the hydromuscovite scales found in hornblende-schists, gneisses, and granites may originally have been biotites which have undergone alteration in the manner described.

The Author has also subjected lepidomelane to the action of pure and of carbonated water. In the former case hydration only resulted; but in the latter liquid, in addition to hydration, loss of iron was brought about by the action of the carbonic acid.

When any ordinary hydrobiotite, such as voigtite, vermiculite, or pyrosclerite, was exposed for a lengthened period to the action of carbonic-acid water, it was noted that the mineral invariably lost a portion of its magnesia and iron, which were first, by the action of the carbonic acid gas, converted into carbonates, and then, as such, removed in solution.

In concluding, it appears to the Author that a fact, which he has by careful observation ascertained, should be recorded here, viz. that whenever anhydrous micas, or lower-hydrated micas, become hydrated, or more highly hydrated, they always at the same time *increase in bulk*. This fact may help to explain what has never been well understood, the nature and an important cause of the rapid weathering of micaceous sandstones.

* After exposure to the air for a day or so, this residue darkened and browned somewhat, owing, of course, to the oxidation of the iron present.

23. *On the* Ashprington Volcanic Series *of* South Devon. By the late Arthur Champernowne, Esq., M.A., F.G.S.* (Read May 8, 1889.)

(Communicated by Prof. A. Geikie, LL.D., F.R.S., F.G.S.)

Introduction.

There exists in South Devon an extensive series of igneous and quasi-igneous rocks occupying a considerable area, mainly east of the River Avon, which have as yet received scarcely more than passing notice, and the study of which is attended with much perplexity

Sir Henry De la Beche† noticed the Yalberton trappean rocks south-west of Paignton, which are included in our subject, and spoke of them as interposed between the Yalberton limestone and that of Watton, which forms the western termination of the Berry Head mass. The relations of the igneous rocks to the Devonian limestones will be considered *de novo* as we proceed.

Dr. Holl‡ mentions the rocks of this series in the neighbourhood of Totnes, Ashprington, &c., as "thick slates, in which much volcanic matter is disseminated." He observes that "volcanic rocks are frequent," and that "beds which are light-coloured often yield a red soil." This was written with reference to rocks which occupy the ground between Harberton and the Dart. Though we might reasonably take exception to the term "slates" as not strictly applicable to any portion of these rocks with which we are acquainted, yet as it is quite certain that Dr. Holl well appreciated the importance of the group, and as no spot could be pointed out where they attain a greater development than [at] Ashprington and its neighbourhood, the provisional term "Ashprington volcanic series" has been here retained.

Many patches and lines of "greenstone" were laid down by De la Beche within the tract of country to be described; but these represent only a very small fraction of the actual spread of the rocks, which occupy on the east of the Avon a large part of Diptford, Harberton, Totnes, Ashprington, Cornworthy, and Dittisham parishes, and on the east of the Dart, Berry Pomeroy, Stoke Gabriel, and Churston Ferrers.

On the west of the Avon they range through North Hewish and Ugborough towards the Yealmpton and Plymouth district, but are

* [The MS. of this paper was found by Mrs. Champernowne among her husband's papers after his death, and was handed over to me. I believe it to have been intended as an instalment of a general description of the Devonian rocks of the Totnes district, which, at my request, he had agreed to prepare. Though incomplete and evidently the first rough draft, it possesses much interest as an expression of some of the latest views of one of the most careful geologists who ever studied the rocks of Devonshire. The map to which reference is made is the 1-inch Ordnance Survey Sheet, no. 22, which was coloured after an original geological survey by the author. This work was presented by him to the Geological Survey, and it will be embodied in the new edition of the Survey Map (no. 22) now in preparation.—A. Geikie.]

† Rep. Geol. Cornwall, Devon, and West Somerset, 1839, p. 72.

‡ Quart. Journ. Geol. Soc. 1868, vol. xxiv. p. 434.

less expanded than on the east of that river, partaking of the narrow folds into which the country is thrown immediately south of the granite. To the north of the parallel of Paignton and Brent they nowhere occupy a large continuous area; nevertheless various tuffs seen in the Dartington, Kingskerswell, and Ogwell districts ought probably to be placed in the same category from their relations to Devonian limestones, although not attaining the development that the series exhibits on the banks of the Dart. Lavas, frequently amygdaloidal and vesicular, or even scoriaceous, but at other times very compact or aphanitic, constitute a great part of this series. They are either altered porphyrites, or basalts, or both. Tuff-beds are largely intermingled with them, all these rocks being highly basic in character. It is possible that some beds of purely detrital origin may be here and there interbedded (if not doubled in), but, so long as we have only the imperfect one-inch maps, they are too insignificant to be shown on paper. Some reddish schists, for example, are met with in a road descending from Weston within a mile east of Totnes to the head of the valley leading down to Fleet Mill.

The lavas, where freshest, are usually of a blackish-green colour, often porphyritic in structure, from the presence of crystals of felspar, which sometimes in hand specimens appear as dark as the groundmass. These harder rocks appear to run in lines, and have even been represented as dykes on the map, as, for instance, at Sharpham on the Dart, but they dip with the rocks among which they occur, and even pass into them. It is true they form projecting bosses by the river-bank, but it would be impossible to trace them away from the foreshore. I believe they are not dykes, but are simply intercalated, and I know of no single instance of a line of hard rock cutting across the strike.

Sometimes the lavas become flaggy, breaking into irregular, long, wedge-like flags, weathering brown or purplish near the surface, and even splitting up into a shaly substance, from which, nevertheless, a perfect passage can be traced into the compact, dark rock used for road-metal; and these facts can be observed in one and the same quarry, as, for instance, in a quarry by the roadside on Totnes Down Hill.

A mass of this rock at "Red Hill" or Pheasant's Hill quarry, Totnes, where it rests on limestone, as further to be described, is weathered brown on one side, but abruptly changes its colour to a deep red on the other, where I noticed a knob of limestone, immediately under the "trap," coated with a thin film of hæmatite.

In a plantation above Sharpham Lodge, near Totnes, the rock is amygdaloidal, as often happens, the cavities being filled with a yellow powder, which appears to be pure limonite, and is doubtless a product of decomposition.

At Broomborough quarry, also near Totnes, there occurs a singular rock, evidently included in this series, of a dull purplish and brownish colour, in which patches and strings of a greenish, felstone-like substance resembling porcellanite are included, with amygda-

loidal kernels interspersed. At a small quarry above Allabeer on the right bank of the Dart and elsewhere some purplish and yellowish flecked shales are seen, the paler patches having a steatitic aspect.

Again, the lavas are often highly calcareous, probably from subsequent infiltration, and as they are both aphanitic and sometimes flaggy, as above mentioned, they appear (without always assigning definite names, such as "porphyrite" or "basalt," to rocks which are so highly altered) to correspond to descriptions of "slaty calc-aphanites," even leading towards "schalsteins."

Of the fact of such alteration, the microscope leaves no room for doubt. The felspars are blurred, as if changing to saussurite, like the felspars in the Lizard gabbros; or they exhibit a veined appearance. Some unaltered augite is usually present, as also a plentiful sprinkling of magnetite or ilmenite; but owing to the extent of alteration the thinnest sections let very little light pass.

Nowhere do true grits appear to form any part of this series; it is somewhat perplexing that the purple grits of Cockington, Beacon Hill, and Windmill Hill, which support the Triassic rocks of Paignton, do not apparently extend across the Dart between Totnes and Sharpham, as the same beds do south of Greenway and Dittisham. However, with the exception of a narrow strip which appears to be thrown down by a fault, and some beds at Langcombe Farm, they certainly form no feature south-west of a line extending from Langcombe Cross to Stoke Gabriel. There are some signs of a N.W. and S.E. fracture bearing south-easterly for many miles, and its existence between the south-west of Ash and Stoke Gabriel was mentioned by Dr. Holl. If these strips really belong to the slaty beds at the base of the Cockington grits, then they overlie the volcanic series, and are thrown down by faults sensibly at right angles to the one just named, but they disappear before reaching the Dart.

Were it not that the greenish aphanitic rocks can be actually observed passing to a deep red, the outlines of the felspars being still traceable, one might be inclined to regard all the soft, raddled, earthy-looking rocks as tuffs; but for the reason just stated we could not safely do so. The quantity of magnetite or ilmenite which appears in every section I have had cut would furnish a ready source for any degree of peroxidation; some sections, when seen by reflected light, show these specks turned brown, and when this destructive process is carried far enough, all distinctive characters of the rock are lost. These decomposed rocks generally yield freely to the knife, differing in this respect altogether from grits of Devonian age.

Iron-ores, both hæmatite and limonite, are occasionally found among the red rocks, as we might naturally expect, but their mode of occurrence is apparently so capricious that they have never been profitably worked for any length of time. I am indebted to Dr. Pridham for information on this point. In Cornworthy parish, on each side of the lane leading north-east from the village to Tuckenhay

Creek, there are some very old excavations which I have noticed myself, but could not then understand them. They were doubtless worked for iron long before the memory of man. The tradition of the inhabitants carries them back to Roman times. In one of these Dr. Pridham discovered a specimen of *Orthoceras*, or perhaps *Actinoceras*, with the siphuncle inflated between the septa and striated internally, a *Cardium*-like bivalve, and a small specimen of *Stromatopora*, all converted into hæmatite, besides some fibrous specimens of the same. On Mr. Studdy's land (Waddeton Court*) on the other side of the Dart, and also near Stoke Gabriel, limonite has been found.

Relations with Devonian Limestones and Slates.

The Northern Limits.

Respecting the age of the rocks, of which so very inadequate a sketch has just been given, we find much that is suggestive and much that is very perplexing, even after their outlines have been laid down on the map, on account of their irregular mode of occurrence.

In examining the principal sections in some detail, we will begin with the east bank of the Dart at Totnes. The "Red Hill" quarry has been already mentioned: Mr. Godwin-Austen noticed this quarry as showing trap resting on faulted Devonian limestone and slate†; whatever appearance the quarry may have presented when he examined it, it is now perfectly clear that the step-like surface of the limestone is not due to step faults, but that it has been eroded into small crags of the height of * * * to * * * feet on the outcrop side, the intervening hollows having been filled in by the "trap," which forms all the upper part of the quarry. The limestone beds below dip E.–S. at * * *.

Interesting as this section is, we must not too readily assume that, because of the disturbance and erosion of the limestone, a geologically vast space of time necessarily separates the two rocks, as that must depend upon what can be learned respecting the upper surfaces of the overlying mass, whether, in fact, we can find them dipping beneath higher members of the Devonian series.

Tracing the line between the limestone and superincumbent rocks, we find it extending nearly to Truestreet, where it is shifted further to the south-east by a N.W.–S.E. fault passing Weston with upcast on the east. For the details of this broken bit of ground I must refer to the map. Thence the upper rocks continue to Langcombe Cross. The great N.W.–S.E. fault from Gatcombe to Stoke Gabriel here cuts them off; they cannot be traced further to the north-east in their line of strike. So far there have been signs of discordant relations, but perhaps not greater than we might expect to find in a reef district, supposing it to have been also the arena of contemporaneous volcanic outbursts.

* Watton Court on the Ordnance Map.

† Trans. Geol. Soc. 2nd series, vol. vi. pl. xlii. fig. 4.

Beyond the great fault a coarse tuff is found at Ash, thrown on the east against some beds of coarse dolomite, which contain clear quartz and lie nearly horizontally. This tuff consists chiefly of red slaty-looking patches, decomposed felspar crystals, and grains of quartz. A precisely similar rock resting on limestone occurs near Watton [Waddeton] village, and beds of like constitution, but not red, are interstratified with bluish slaty shales over the Dartington limestone, being well exposed in the Ashburton railway-cutting, also overlying the limestone of Bulley Barton, and south of the limestone of Clennon Hill near Goodrington, where it would appear that they rest on an uneven surface. These belong to a characteristic type not specially mentioned in the first part; they are never amygdaloidal, and cannot have flowed, but seem to correspond to the Nassau "porphyritic schalstein" so-called.

The next exposure east of Ash occurs in the lane leading from Higher Yalberton to Windmill Hill, but it throws no clear light on the relations. Fine-grained flaky tuffs forming the floor of the lane appear to dip east, and just before reaching the purple grits of the high ground some hard aphanite protrudes. No junctions are visible here.

On the east of Higher Yalberton the limestone forms a narrow crest broken by two faults, but otherwise continuous with that of Clennon Hill over Goodrington Marshes, where it abruptly ceases on its strike, but can be followed across the narrow gorge on the south as far as the Brixham highroad near Crabb's Park. Here for a few chains it is in contact with the mass extending towards Watton village, which has the volcanic rocks dipping against it on the west. Clennon Hill is bounded on the east by a fault bearing N.N.E. through Paignton, which is very conspicuous from its shifting the Triassic boundary nearly half a mile to the south from the east end of Primley Hill. It passes just east of Crabb's Park, throwing down slaty shales and grits, and after bringing limestone against limestone, as mentioned (a point of minimum "throw"), sets on again with an opposite throw following the line of the Watton road, and comes out on the bank of the Dart, a short distance west of the Watton boat-house, bringing down the raddled volcanic rocks on the west against grey and purplish slates that dip under the Watton limestone, the dips at the junction being widely divergent. To complete this bit of ground, we recross north-west from the Watton and Paignton road to Higher Yalberton, and find all the intervening ground to consist of the trappean rocks, the narrow crest of limestone east of that place clearly dipping south under it. The north side of this crest is much more obscure in its relations than the south, and the same remark applies to that of Clennon Hill. Dr. Holl considered it to be "doubled under" higher rocks "with inverted dip"*. I do not feel satisfied on this point. A patch of limestone shown on the old map south of Goodrington marshes must be expunged, as the ground consists of slates and grits. There are other faults shown on the map, but not described.

* *Op. cit.* p. 431.

The next patch of volcanic rocks brings us to the coast of Torbay. It lies east of Goodrington, forming the "Sugar-loaf" hill, of less elevation than the limestone plateau to the south. A hard aphanitic rock protrudes for a short distance along the top, but does not reach the railway-cutting close to the cliff, where it is flanked by tuffs. This patch throws off some beds of iron-shot limestone to the north, dipping north and exposed in the cutting. The face of Saltern Cove is a N. and S. line of fault, which has shifted the iron-shot limestone on the foreshore south of its exposure in the railway-cutting, and the Triassic outlier of the North Cove at Saltern, south of that at Milepost 223. The fault continues to the south at Broadsands, throwing down a strip of Triassic sand-rock that dips east, and again forming the face of the cliff.

The above-named limestone is undoubtedly on a higher horizon than the great mass of Goodrington Hill, Brixham, and Berry Head. It abounds in corals—*Favosites cervicornis*, Edw. & H., *Alveolites*, sp., *Cyathophyllum cæspitosum*, Goldf., and simple forms, *Stromatopora*, Crinoids, and more rarely *Acervularia* (sp.). The layers are parted by a red clay. At the foot of the cliff in the main cove the tuff exposed is identical with a piece of Schalstein from Weilburg, Nassau, in my collection. The beds succeeding the iron-shot limestone consist of purple marly shale, and include the interesting fauna identical with that of Budesheim worked out by Mr. Lee*. Higher still, immediately under the Trias, they are more slaty and are interstratified with purple grits. Therefore eliminating the faults and disturbances, [owing to] which cause the beds [are much contorted, so that they] hang nearly vertically towards the north-west, the relations are as follows†:—

Section near Goodrington.

6. Triassic conglomerate.
5. Hard red grits and slates.
4. Purple and blotched marly shales (*Goniatites, Bactrites, Cardiola retrostriata*, &c.).
3. Iron-shot limestone bands (very fossiliferous).
2. Schalstein: and aphanite nucleus? not reaching the cutting.
1. Chief Devonian limestone.

Following the Belgian and German classification, 3, 4, and 5 would certainly be considered Upper Devonian‡. Much of the red colour may be due to percolation through the Trias; but the beds may contain the sources of peroxidation in themselves, as has been proved in the case of the lavas. In the railway- and road-cutting adjoining the Naval Hospital§ we have again the beds No. 5 well exposed and dipping northerly, and, after an interval of level ground,

* Geol. Mag. 1877, p. 100.

† [The drawing intended to accompany this description has not been found among Mr. Champernowne's papers.—A. G.]

‡ The tracing-out of calcareous horizons in South Devon, corresponding with 3, must remain for another communication.

§ Now a private residence.

the Trias escarpment of Roundham Head follows. In fact wherever the base of the Paignton Trias is found, the underlying rock is the same* (Cockington "old red"), only to the east of the Paignton N.N.E. fault this forms low depressed ground, instead of rising into bold features like Windmill Hill and Westerland Beacon.

Thus, when once in No. 5 we have reached a clear horizon, [the beds of] which throughout South Devon, including the Staddon Point and Picklecombe grits in Plymouth Sound, are free from igneous intercalations; they are done with.

Accordingly the chief problem consists in satisfactorily piecing together the Berry-Park slaty shales, the igneous masses, and the limestones No. 1. As to the first, which extend through Little Hempston into the Dartington trough, it is improbable that they are represented by 3, 4, or 5 (which, for practical purposes, may be considered one group). Apart from colours, they are utterly unlike them, and descending from Windmill Hill to the Yalberton limestones, not a vestige of the Berry-Park slates is to be seen, only the strip of tuffs as described.

This would appear to point to an unconformity perhaps between 2 and 3, and it must be confessed that the appearances in the railway-cutting would favour this hypothesis. In the remaining part of this paper we shall hope to throw some light upon these relations.

The Southern Limits.

These commence at Sharkham Point on the east, but the igneous series is not conspicuously developed until we pass the Torquay and Dartmouth road, when we find Brim Hill above Galmpton Mill and nearly the whole of Greenway Hill to consist of them; continuing by Dittisham they extend to East Cornworthy, where they are shifted to the north by a fault. From the bank of the Dart, near a barn marked on the map, a good boundary runs right along the village of Cornworthy, by Priory Gate, following the bottom of the Washburton valley to Middle Washburton, beyond which I have not yet satisfactorily followed it†. This last trace separates dark-coloured lavas on the north as exposed at many points in ground which is often deep red (due to causes already explained) from [the] bluish-grey slaty shales which overlie them on the south side.

At the south end of Mudstone beach a very clear passage can be seen from the grey shales into the superincumbent limestone, and at Sharkham Point the limestone beds are vertical, and parallel with them is a sheet of compact greenstone, forming the point of the headland.

I spoke of this as intrusive, but have since seen reason to doubt the correctness of this opinion. At a short distance west a steep

* Dr. Holl, *op. cit.* p. 434.

† [On Mr. Champernowne's map the boundary is shown to be shifted about a quarter of a mile to N. by fault at Middle Washburton, and carried on for a mile on south side of Higher Washburton Houses.—A. G.]

climb through the brushwood shows one a detached patch of limestone, which certainly appears to double back upon itself. It is possible that this may after all be only a lenticular patch, as it is difficult to get close to it. But be this as it may, a fuller knowledge of the mapping proves me to have been in error in suggesting that the contorted grits of Southdown Cliff were older beds than the limestones, rolled up.

We now take the principal points of interest from Sharkham Point (where we have a base) to the limestone, unseen in the Goodrington section.

At Higher Brixham the outcrop of the limestone makes a marked feature at the back of the church, and at Upton lane, at the foot of the ascent, red grits at once come on, which must here rest directly on the limestone without even the igneous rocks between.

With a quarry near Laywell House the Higher Brixham limestone terminates; but as the beds dip north-east at low angles it is clear that it is not thinning out on its strike at this precise spot, but dips away from a fault, which throws down the country on the west, and surface-stones prove the lavas to be represented near the foot of the hill at Churston Mill. If this termination is not a fault, there is no escape from the alternative that the red grits must cover up the continuation of this limestone by a great unconformity. I believe the fault to be the explanation. Beyond Lupton House the relations are most perplexing. There is no evidence of the presence of the igneous rocks along the Dartmouth road from the boundary of the Churston limestone, and instead of them we find grey slates extending for a mile and half, and the purple grits, which at Higher Brixham rest directly on limestone, are not encountered until past Lupton Higher Lodge, near the track leading to Higher Lupton (in a field N.E.), a small quarry showing them dipping S.E. at * * *. De la Beche's arrow-dip west (15°–20°) near Churston Station is correct. The grey slates for the first half-mile from the limestone boundary, although not immediately exposed, slope when seen towards the north with the fall of the ground; but after the bearing of the road changes they appear to have arched over, as they dip steadily E. of S. in the direction of the road. This is near the third milestone from Dartmouth.

The question arises on what horizon these slates are. It seems to be the general opinion that the soft grey slates on the south side of Galmpton Creek are the continuation of the Mudstone Slates; they are much like them, and, if so, they must be older than the bulk of the limestone, which dips towards them near the boundary, no junction being seen. Now, however, we have a dividing horizon south of Galmpton, inasmuch as the lavas begin to form a well-marked feature (a small patch occurring east of the railway extending to Greenway Ferry, [while] near the top of Greenway Hill, in a wooded escarpment, I collected a specimen identical with the Nassau amygdaloidal schalstein). They overlie the grey slates at Galmpton Creek; they constitute Brim Hill, and dip S.E. 17°, at the mouth of the Greenway Tunnel. Continuing the section, we

have bluish flaggy slates of the type of the Berry-Park slates over the lavas, &c., striking parallel with them in the lane leading to Greenway Farm. They continue beyond the farm to the wood, where the purple grits appear across the river, and strike down by the south side of Marlpool. Dr. Holl has continued the section from here to Kingswear, along the railway. Some grey slates with a few calcareous seams line the north side of this inlet, and rising from below them a great mass of lavas and tuffs, with some very hard rock, forms the ledges, until we round Greenway Quay and reach their base. Along the bank from here to near Galmpton Mill some beds of dark limestone and buff-coloured shale extend. They are exceedingly rich in corals, the prominent forms being *Alveolites* (*compressa*?, Edw. & H.), large specimens of *Cyathophyllum damnoniense*, Phil., and others. *Cystiphyllum vesiculosum*, Goldf., also a specimen of *Hallia* occurred, [the latter] with a quantity of *Aulopora* hanging about it. From the bend at the mill to the head of the creek the mudstone-like beds complete the tour of this ground.

We may now review the facts that have been adduced, and try to get at their general meaning.

In the first place, from what has been said, it will be seen that we regard the mass of these igneous rocks as truly intercalated in the Devonian deposits, and consequently that the facts observable at Redhill quarry and other spots near Totnes are only cases of contemporaneous disturbance and erosion of a quite subordinate character. More depends, however, upon how we understand the limits of the larger limestone masses. It must be admitted that the evidence on this subject is not so clear as one might wish. I quite agree with Dr. Holl, speaking of the Totnes district, that the limestones have, on the whole, been "dislocated from the slates, so that their boundaries are virtually lines of fault."

The country, indeed, is shattered by faults. Although it is often difficult to distinguish the slates below the limestone from those above, yet with experience one can detect a difference in the Berry-Park slates from those which clearly dip under the Dartington, Berry-Pomeroy, &c. limestones*. But why should there not also be slates neither exactly above nor below the limestone, but replacing it? so that De la Beche's words would also be true, viz., that "the geological continuation of certain limestone appears to consist of slate."

Discussion.

The President said that the thanks of the Society were especially due to Dr. Geikie for having rescued this paper from oblivion.

Dr. Geikie, after alluding to the melancholy interest attaching to the paper, said that he had himself urged the Author to formulate his ideas upon the structure of the country. The present communication, however, was all that was found among his papers, in

* Note.—A specimen in my collection of Kramenzel-schiefer, from Adorf, Waldeck, strongly suggests comparison with the coarser beds of the Berry-Park slates.

a condition for publication. But it is imperfect, and no materials remained from which it could be completed; still it was too valuable a piece of work to leave unpublished.

There were two principal points in this last work of Mr. Champernowne:—(1) the non-intrusive character of the beds in question; (2) their geological horizon, regarding which, though, owing to the faulted nature of the country, it is rather obscure, Mr. Champernowne's surmises may turn out to be correct. There was no allusion in the paper to the compression and shearing the rocks had undergone, to which he (Dr. Geikie) attributed much of the schistose structure both of the sedimentary and igneous rocks of the region. The flaky beds of which the Author speaks can be traced into the more massive rocks. The flattening-out of the amygdaloids was a striking proof of this mechanical deformation.

Mr. Rutley referred to the general soundness of Mr. Champernowne's conclusions; there were some interesting points in connexion with these lavas. He had himself noticed important differences in the volcanic beds on the east and those on the west side of Dartmoor respectively. On the east they were mostly porphyrites, on the west schistose lavas and basalts, the schistose beds being very characteristic of the Brent-Tor district, of which he considered the Saltash lavas were a continuation. No perfectly satisfactory explanation of the causes of this schistose character had yet been given. He had not hitherto observed any mechanical deformation of the amygdaloids in the schistose lavas, such as those of Churlhanger, and this, he thought, militated against the assumption that the schistose structure was due to shearing. He referred to the boundary between the Carboniferous and Devonian as having been drawn along belts of igneous rock, which were, in point of fact, repetitions of the same bed. He referred to the new line of railway as likely to throw some light upon the district west of Dartmoor.

Dr. Hatch spoke of the rocks from Ashprington as tuffs and diabases, mostly aphanitic, but sometimes porphyritic. They were not very suitable for microscopic examination, owing to their advanced stage of decomposition, the felspars being turbid, the augite having mostly passed into chlorite, the ilmenite into leucoxene, and there being an abundance of calcite. Where at all fresh there were traces of ophitic structure. In some cases the amygdaloidal rocks showed traces of shearing. The tuffs closely resembled the "Schalsteins" of Nassau and the Hartz.

Mr. Worth said that the volcanic series had occupied much of his attention, and that practically the rocks under discussion were similar to those in the neighbourhood of Plymouth. He differed from Mr. Champernowne's conclusion as to their horizons, especially as regards the Plymouth district. He was of opinion that they underlie the Plymouth Limestone, and that on this horizon may be traced the beginnings of a coral reef.

He referred to the new line on the west side of Dartmoor, and to the light it was calculated to throw upon the geology of the district, especially in reference to the volcanic rocks. Alterations

in some of the lavas were so gradual that one can hardly see where they begin or end. There were also *intruded* volcanic rocks of a similar character. Referring to the errors in the mapping of the boundary between the Carboniferous and Devonian of this region, he asserted that the town of Tavistock is actually on the Carboniferous, and yet that by a complex series of foldings the Devonian is brought up north and south of it. He spoke of trap dividing a series of "Schalstein" beds; elsewhere two distinct lava-flows might be noticed, one above the other.

Mr. W. W. Beaumont criticized some of Dr. Hatch's remarks with reference to the alleged traces of shearing in the vesicular lavas, based partly upon the assumption that shearing would destroy the continuity of the cavities; and

Dr. Hatch pointed out that, according to his view, the cavities having been filled at the time that the shearing took place, they must be regarded as solid bodies.

24. *The* Rocks *of* Alderney *and the* Casquets. By Rev. E. Hill, M.A., F.G.S., Fellow and Tutor of St. John's College, Cambridge. (Read May 8, 1889.)

1. General Description.

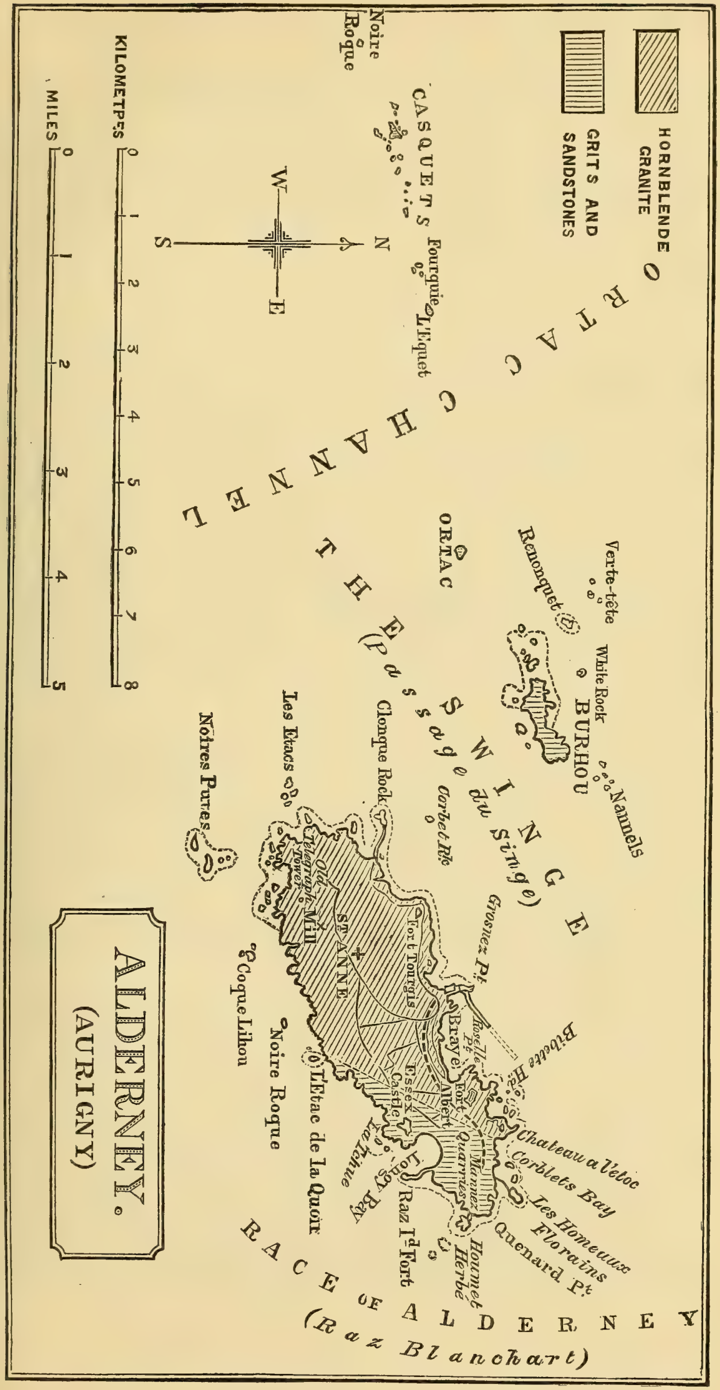
Alderney is seldom visited and has been seldom described. It deserves both description and visit. Macculloch gives an account of it in the first paper of the first volume of our 'Transactions.' Ansted, in his 'Channel Islands,' notices many features with accuracy, and seems to have taken a special interest in the place. Since his time I am not aware of a single addition to our knowledge until the admirable map of France by MM. Vasseur and Carez, sheet No. IV. N.E. of which assigns colours and letters to the island. After the first draft of this paper had been written, a paper by M. Bigot* came into my hands, containing, besides notes on Jersey and Guernsey, a brief but excellent description of Alderney, which includes several of the facts that I have independently discovered.

I have to thank Professor Bonney for invaluable notes on the rock-sections, which he has allowed me to incorporate in this paper.

Alderney is an oval island (see Map, p. 381†), about 3½ miles long by 1 mile broad, lying E.N.E. to W.S.W. The western portion is a tableland just over 300 feet in height, which, along the west and south, falls in grand cliffs to the sea, but slopes to the shore along the north-western side. The eastern extremity is separated from this by lower ground and the deep indentation of Longy Bay, but above the Mannez Quarry and at Fort Albert there are elevations of 140 feet and 180 feet respectively. Distant about a mile and a half to the W.N.W., across a channel called The Swinge, lies Burhou, an uninhabited island, with nearly a mile of rock available for examination when low tide lays bare the reefs to the west. Around it is an archipelago of rocks, the Verte Tête, the Nannels, Les Macquereaux, exposed, awash, or sunken, to ships dangers of every kind and degree, to the fishermen and pilots sea-marks and fishing-grounds. A sunken ridge runs west for some three miles, bearing these and other rocks and reefs, its end marked far over the sea by

* Bull. Soc. Géol. de France, 1888, p. 412.

† This map is drawn on a reduced scale from the English Admiralty chart of "Alderney and Casquets," which visitors should obtain and use. The dotted lines round the shores are intended to indicate areas exposed at low water. The broken line marks the railway-track; some of the roads are shown by continuous lines. Cap La Hague, the nearest point of the mainland, is distant a little less than 10 miles, due east across the Race of Alderney.


HORNBLENDE GRANITE
GRITS AND SANDSTONES
ORTAC CHANNEL
THE SWINGE
(Passage du Singe)
CASQUETS
Noire Roque
Fourquie
L'Equet
ORTAC
Renonquet
Verte-tête
White Rock
BURHOU
Nannels
Corbet Rk
Clonque Rock
Les Etacs
Noires Putes
Grosnez Pt
Fort Tourgis
ST ANNE
Old Telegraph Tower
Mill
Braye
Roselle Pt
Bibette Hd
Fort Albert
Essex Castle
Mannez Quarries
Chateau a l'étoc
Corblets Bay
Les Homeaux Florains
Quenard Pt
Houmet Herbé
Raz Id Fort
Longy Bay
La Tchue
L'Etac de la Quoire
Noire Roque
Coque Lihou
RACE OF ALDERNEY
(Raz Blanchart)
N
S
E
W
KILOMETRES 0 1 2 3 4 5 6 7 8
MILES 0 1 2 3 4 5
ALDERNEY.
(AURIGNY)

the isolated dome of Ortac. Then follows the deep and clear Ortac Channel, in breadth about a mile, and across this to the west another similar ridge, two miles long, emerges at its extremity into the lonely group of rocks called the Casquets, which support the great lighthouse of that name, outermost sentinel of the Archipelago.

The dry-land surface in the region treated of cannot reach five square miles, but it is scattered over an area ten miles long. This paper accordingly deals with the geology of a considerable tract, not much inferior to Charnwood Forest in dimensions, and with nearly as much rock above the water as in Charnwood emerges from the Triassic clay.

2. Principal Igneous Masses.

Alderney itself consists mainly of a rock commonly called granite. This constitutes the whole of the west and centre of the island. It has been worked in various quarries, especially the great one west of the harbour, and is well exposed along the north-west coast. To the eye it shows felspar, often conspicuously striped, much black mica, hornblende in very varying amounts, and some quartz, generally sufficient in quantity to render the popular name correct. The constituent minerals occur in particles about $\frac{1}{8}$ inch across over most of the area, but east of Fort Albert the rock is rather finer in grain. It is generally very well crystallized: one specimen only, from Telegraph-Cable Bay, has an amorphous appearance, perhaps an effect of some intrusion. Under the microscope the biotite is seen to be sometimes replaced by aggregated flakes, possibly chlorite.

On the shore beneath Fort Tourgis the usual dark rock weathering grey is intermixed with a paler rock weathering pink which contains much more quartz than is usual. I am inclined to regard this as different, but the question requires closer examination. It is surely not necessary to assume that every coarsely crystalline mass is throughout of simultaneous date, any more than are the basaltic plateaus of Antrim and Mull. The owner of one large quarry declared to me that it furnished eighteen different qualities of stone. The quarry referred to contains several dykes; still, most of these qualities must have been varieties of the mass which those penetrate.

At one locality there can be no doubt that we find a granite distinguishable from the rest. This constitutes the extremity of the promontory on which stands the fort called Château à l'Etoc, Bibette Head, and the rocks and islets in the intervening Baie de Saie. Most is much decomposed, but on Bibette Head it has been quarried, and can be seen to consist normally of white felspar, quartz, black mica, and hornblende in unusually well-shaped crystals, nearly $\frac{1}{4}$ inch in length. The assemblage forms a beautiful white granite. Under the microscope sphene and hæmatite or magnetite can be recognized, and the occasional imbedding of small felspar crystals in quartz is interesting. The line of division between this white

granite and the normal darker rock may be seen sharply defined in the bay south of Bibette Head.

A granite similar to the pink decomposing form of this occurs in outcrops on the southern cliffs; as, for instance, on a slope north of the islet called Coque Lihou, where a pink and a bluish rock may be seen in intrusive contact. Some of this pink rock recalls the L'Erée gneiss in Guernsey, and itself shows under the microscope signs of disturbance. A specimen collected from somewhere on these cliffs of this circle shows a very large orthoclase crystal $\frac{3}{4}$ of an inch long, such as characterizes the granite of Cap La Hague, on the neighbouring coast of France; such crystals also characterize a rock at L'Erée. The perpendicular cliffs of this coast, even more inaccessible than those of Sark, swept at their base by some of the most violent tides in Europe, offer serious obstacles to examination.

The only locality where I have noticed crush-structure on a scale visible to the eye is on the shore under Fort Tourgis. Here are seen many dark node-like patches, some narrow and lenticular, and of these the axes lie with a certain amount of parallelism, while the rock itself has a rude appearance of a structure which is directed N.E. to S.W. and vertical.

The general appearance of the normal Alderney rock recalls the diorites and syenites of Guernsey, and some specimens can scarcely be distinguished from some of the quartzose varieties of that group. But the abundance of mica, and the smaller amount of hornblende, would connect it rather with the granites of Jethou and Sark. The microscopic study has resulted in a similar opinion.

3. Minor Igneous Rocks.

The minor intrusive rocks of Alderney do not equal in interest and variety those of Guernsey, still less do they rival the singularities which Jersey presents. Nevertheless, they are numerous and interesting. Most of the families found in the other islands are represented. Granites occur here and there: one, for instance, about a yard thick in the sides of a chasm in the crags north of Fort Albert. Pink micro-crystalline quartz-felspar dykes are most abundant; the western headlands are cut by many so parallel that an observer from a boat might even think the rock stratified, and so abundant, that I estimated them to occupy more than one tenth of the cliff-face. They appear to be identical with the Guernsey quartz-felspar dykes (Quart. Journ. Geol. Soc. vol. xl. p. 416).

Compacter pink dykes occur from Braye Harbour westwards, which may represent the pink felsites of Guernsey. A remarkable purple intrusion, several feet thick, may be followed some hundreds of feet along the shore west of the causeway leading to Fort Clonque, and ultimately appears to transform itself into a variety of the last-named group. Under the microscope this shows a very compact matrix speckled with opacite, and containing small crystals of felspar. The matrix exhibits a minute devitrification, and the rock might perhaps be called a porphyrite. Basic intrusions are less

frequent than acid. Diabase dykes, so abundant in Guernsey, occur, but not in the same profusion. A very large one cuts the granite west of the fort called Château à L'Etoc: there is another under the west wall of Fort Albert. The largest I have seen cuts the cliff of the Mannez Quarry, the great quarry where the railway ends. This last is called by M. Bigot an andesite. It is so decomposed that determination is difficult: my slide seems to be a fine-grained diabase. It will be shown hereafter that this is certainly later than most of the intrusions.

Like all the other islands, Alderney has its mica-trap dyke. This occurs at the east end of the Mannez Quarry, where the cliff-face, not now worked, is only some 15 feet high. It forms two or three vertical sheets about a yard thick, and does not seem to have altered the rock which it penetrates. Decomposition has reduced most into a brown earthy mass, but the centre of a spheroid contained a small kernel in tolerable condition, from which a slide has been cut. It shows abundant brown mica in well-shaped hexagonal plates of variable size, some reaching ·5 inch in diameter. The felspathic matrix appears to have been a glass crowded with lath-shaped felspar crystallites. Besides granules of iron-oxide, there may be apatite and a little sphene, and there may have once been a pyroxenic constituent. The rock belongs to the Kersantite group of the mica-traps.

The most interesting intrusion is one which forms a thick mass on the beach and in the crags on the west side of Fort Albert. It occupies some 70 yards of the shore, but immediately inland splits up into dykes, which may be seen in the scarp beneath the outer lines. This rock I have not found elsewhere. I took it to be the same in composition as the great mass at Bon Repos Bay in Guernsey, which it externally resembles. Professor Bonney recognized its true nature, and has kindly given me the materials for the following description. Its specific gravity has the high value of 3·003. Macroscopically, it is a very dark holocrystalline rock containing large crystals of a pyroxenic mineral, whose glittering divisional planes are interrupted by dark spots. Under the microscope the pyroxenic mineral is seen to dominate, and is exhibited in various stages of transition from an almost colourless augite to a brown and, occasionally as a final stage, green hornblende. This specimen confirms the view that there is a true conversion of augite into hornblende. For instance, the slide cuts through a large pyroxenic crystal of irregular outline. The outer and greater part is of a strong brown, with a slight olive tinge, markedly dichroic. In the middle is a grain of colourless augite exhibiting the close cleavage of diallage, and with the proper extinction. Little filmy offshoots from the hornblende penetrate its boundary, and in some places are intercalated irregularly between the cleavage-planes, in a way that resembles a formation *in situ* far more than an intercalation by enclosure. Small grains of olivine are enclosed in this crystal; larger ones are intercrystallized with the other constituents, and are more or less converted into serpentine in the usual way. There are

some grains of felspar, so far as can be seen plagioclase, but as a rule much decomposed, some flakes of rich-brown mica, and iron oxides as usual. The rock may be called a picrite, though, like some of those in Anglesey and at Little Knot, it has rather too much felspar to be a typical example.

This occurrence is to me of interest as being my first case from these islands of an olivine-bearing rock. The scyelite from Sark, described by Prof. Bonney in the 'Geol. Mag.' of March 1889 (p. 109), was collected at a later date.

4. The Grits.

The igneous rocks hitherto described occupy the greater part of Alderney, but not the whole. A divisional line (very possibly a line of fault) runs north-east and nearly straight from the cliff-foot opposite L'Etac de la Quoire to the middle of Corblet's Bay. The igneous rocks lie west of this; to the east is a series differing from everything in Guernsey, Sark, or Herm, a sedimentary series, a series of grits. An outlying patch of these about $\frac{1}{4}$ mile long occurs on the southern cliffs, opposite the islet called Coque Lihou. But they are not confined to Alderney. Of them consist Burhou and Ortac, and the whole of the Archipelago between the Swinge and the Ortac Channel; of them also consist the Casquets, and all their satellite reefs. Beds absolutely undistinguishable I discovered on the mainland of France, at Omonville la Rogue, east of Cap La Hague *. With these last M. Bigot identifies some beds which he calls "stéaschistes noduleux" at Tourlaville, east of Cherbourg; and having seen both, I entirely agree with him. From the Casquets on the west to Tourlaville in the east is a distance of thirty miles, accordingly the series we are considering is one of no little extent and importance.

Both Macculloch and Ansted were unable to visit Burhou or the Casquets. The pilot-boat which conveyed me to the Casquets took me within 50 feet of Ortac, and also threaded devious channels of the reefs, so as to give me a good view of the greater number; on a later visit I was able to land on Burhou.

There are ample means for studying the group, since, besides the clean surfaces shown along the shores and in the reefs, there is the range of quarries now or formerly worked to obtain materials for the breakwater. The group is thus seen to be a series of sandstones and grits, consisting primarily of quartz, but with an admixture of felspathic material, which, though variable in quantity, is always too much for a quartzite. Occasionally there are thin beds of a micaceous sandstone. The colour, though generally a greyish white or cream-colour, has often a pinker tinge, reaching even to a deep rusty red; as, for instance, in a quarry north-west of Essex Castle. Every variety occurs of fineness and coarseness, ranging from the above-mentioned mudstones through sandstones and coarser grits up to constituent grains $\frac{1}{4}$ of an inch across. As

* M. Bigot had previously made the same identification in the paper referred to above.

the coarseness increases, so do the angularity of the grains and the proportion of felspar, till we find what seems merely a disintegrated granite, a perfectly typical arkose, of which my best example comes from the Casquets. As might be expected from such materials, current-bedding is frequent; so frequent as to be the rule rather than the exception. We might expect also to find beds of conglomerate. No mass seems to consist chiefly of pebbles, but pebbles do occur. On Burhou I did not detect any; but the manager of the Mannez Quarry said that a single one would often be found in an otherwise uniformly fine bed, and showed me several so found. At the Casquets they are frequent, as also in the quarry north-west of Essex Castle; while in a quarry in the outlier north of the Coque Lihou they are numerous and range up to three or four inches long.

The current-bedding, arkose material, and sporadic pebbles, all point to the immediate neighbourhood of a coast, probably to a coast like the present, with cliffs and beaches, tide-swept races, and wave-washed reefs. And in fact at the outlier mentioned north of the Coque Lihou these grits can be seen reposing on the crystalline rock, an actual portion of the bed of that ancient sea. The rock, too, is not the granite proper, but a mass of one of the pink granitic intrusions which occur so abundantly in the granite *.

The bedding of the series is extremely marked, and may be recognized from a considerable distance. The dip varies; it may perhaps be 60° at Essex Castle, but is usually from 45° to 30°, and in Burhou is sometimes almost *nil*. From the Casquets to Alderney the direction varies between S. and N.E., but on the average, and in general, is S.E. At a spot on Little Burhou, where the shore has cut a horizontal section, one bed makes a perfect letter S in a length of 50 yards; as a rule, however, there is no contortion. I have not noticed any small faults, but it is plain that on a large scale there is much dislocation, for the Burhou beds dip directly towards the crystalline mass of Alderney, and the beds at Omonville are vertical. I cannot make any estimate of the thickness of the series. Sections of considerable length are shown in Burhou and in the quarries. It is difficult to disprove the existence of faults, but no one, I think, can doubt that a thickness of several hundred feet may be seen.

The pebbles and angular fragments, where found, are of various natures; many, perhaps most of the smaller ones, are white milky quartz, some a grey mudstone, some a crystalline granitic rock, one or two very dark, perhaps basaltic: I did not notice any of the local granite, but several seemed to be from the pink dykes so abundant in that mass. Most of the larger pebbles consist of a compact, almost glassy, igneous rock with occasional porphyritic felspars, probably a rhyolite. Such rocks are abundant in Jersey; the dark-brown colour characteristic there is shown in many (one of which I have had cut). M. Bigot mentions a pebble with spherulites, which are also frequent in Jersey; while at Omonville I myself found a

* M. Bigot has noticed this and given a diagram of the contact.

small inclusion showing the striped structure so remarkable in that island, and in the Alderney Quarry, north of Coque Lihou, I saw a fragment larger, but less characteristically marked.

5. Age of the Grits.

Of this nothing has hitherto been known. Ansted only conjectured that they might be Triassic. Now, however, a fairly definite horizon can be assigned to them. It has been shown that they lie unconformably on the granites, and also contain pebbles of the dykes which cut these. Moreover, they are in general not penetrated by the abundant series of dykes. Ansted mentions that "the veins traversing the syenite rock of which the Casquets are mainly composed are said to extend into the sandstone overlying." At my visit not a vestige of igneous rock was to be seen, either as underlying mass or as dyke. On Burhou I saw no dyke. Along miles of the Alderney shore I saw no dykes. The insufficiency of negative evidence is shown by the two dykes already described as seen in the Mannez Quarry and by one on the shore east of the quarry, which perhaps is a continuation: there is, however, abundant evidence that the series is later than the majority of the intrusions. But, on the other hand, the mica-trap dyke in the Mannez Quarry, as it cuts them, gives a posterior limit to their age, for it clearly belongs to the "kersantons" of Brittany, which Dr. Barrois assigns to the close of the Carboniferous period; thus these beds must be far earlier than the Trias. In search of further evidence, I made a traverse of the Cotentin from St. Malo and Avranches up to Cherbourg, and so discovered the beds at Omonville, above described as undistinguishable. These can be seen to rest on a gneissic rock, and are described by M. Bigot as intercalated between the "Phyllades" (of St. Lo ?) and the "Grès Armoricain." In general, on the mainland, it is the "Conglomerat Pourpré" which precedes the "Grès Armoricain." The pebbles in that conglomerate, where I have seen it, are exclusively quartz, and its colour is extremely deep. But the Alderney grits contain quartz in abundance, though other materials as well; and their colour, as has been mentioned, sometimes approaches the "pourpré" tint. We may therefore assign this important series to the Upper Cambrian (of Lapworth) *.

6. Comparisons and General Conclusions.

The north-east corner of Jersey is occupied by a remarkable series of conglomerates. They have attracted the attention of every observer, but there is a singular absence of evidence with regard to their age. Ansted conjectured that they might be equivalent to

* At several points about high water-mark, especially between Forts Quenard and Homeaux Florains, there occur on bedding faces markings which closely resemble organic impressions, and which high authorities thought were referable to *Dictyonema*. But I have since found markings extremely similar to these on joint faces and boulders, which must be of recent origin. [Mr. Etheridge informs me that they are produced by Limpets.]

the Alderney grits; the external differences, however, are great. M. Noury, in his excellent monograph on Jersey, regards them as Post-Permian on the ground of their relations with the rhyolites. MM. Vasseur and Carez, in their map, give them the tint and letter of the "Conglomerat Pourpré." The existence of the Alderney beds shows at any rate that various conglomerates were being formed about that epoch, and the next paragraph will show that the rhyolites afford no contradictory indications.

This singular and almost unique group of rocks (described under the name of rhyolites by Mr. Thos. Davies), which occupies so large an area in the eastern part of Jersey, is conjectured by M. Noury to possess a Permian date (Géologie de Jersey, p. 129), on account, apparently, of its resemblance to certain rocks from the Vosges (p. 30). But the presence of pebbles which proceeded from this group in the grits of Alderney and Omonville, as described above, is alone sufficient to show that the group cannot be placed later than Cambrian times.

The Jersey conglomerate-pebbles consist chiefly of sedimentary rocks which closely resemble the schists of St. Lo, as seen on the mainland opposite and elsewhere. The Alderney grits contain sedimentary pebbles which may well belong to the same formation. If either this identity, or the equivalence of the Jersey beds with those of Alderney, should hereafter be proved, then, considering the time required to harden such beds and wear their fragments into pebbles, we should obtain additional evidence of the Pre-Cambrian age of the schists of St. Lo.

At different parts of the coast of Jersey there occurs, in considerable quantity, a diorite. It is in contact with various other rocks and is intruded into by several, itself intruding into none. There cannot be reasonable doubt that it is anterior to the porphyrites. It is not seen to intrude into the neighbouring argillites of St. Aubin's Bay, which are certainly not later than the porphyrite group, and which M. Noury correlates with the Granville schists of St. Lo. This diorite, then, must be Pre-Cambrian. But both in general appearance and in occasional peculiarities it is identical with the diorites of Guernsey, and affords evidence that these are Pre-Cambrian too. Comparing these again with the hornblendic granite of Alderney, overlain unconformably by Upper Cambrian grits in which are pebbles of dykes found in the granites, and considering also the kindred granites of Sark, Herm, and Jethou, we must recognize the existence over a great area of Pre-Cambrian coarsely crystalline igneous rock.

The granites throughout this area show results of earth-movements to a certain extent; they bear variable traces of crushing, as has been previously mentioned. This amount is not very great, perhaps not more than that to which even the grits have been subjected. But the so-called "Protogine" or gneiss of the Cap La Hague region has undergone a tremendous crush, and has been reduced to a grey gneiss with foliation N.E. to S.W. The singular syenite of Coutances has a strong cleavage N. to S. or N.N.E. to

S.S.W. The gneiss of Guernsey, as described in my paper on that island, has a structure which runs N. to S.; and, as there stated, all evidence that can be found agrees in making it a formation prior to the diorite group. Here, then, we have a set of rock-masses which underwent great earth-movements prior to times which themselves were Pre-Cambrian. I never doubted that the Guernsey gneisses were Archæan, but I did not feel sure that proof of this would ever be obtained. By the assistance of the evidence from Jersey, Alderney thus leads to a proof.

As circumstances render it improbable that I shall be able to undertake further work in the Channel Islands, I wish to take this opportunity of making some corrections in my former paper on Guernsey (Q. J. G. S. vol. xl. p. 404).

It is therein assumed throughout that the main mass of gneiss is a non-igneous rock. I have now no doubt that much of it is igneous and crushed; perhaps all. Ansted's "patch of clay-slate in Rocquaine Bay" discussed on p. 406 may be explained as a case of yielding to crush on a very large scale, and the pockets of coarser material there described can now be fully accounted for as portions which have offered a stouter resistance than the rest; they should accordingly afford an interesting subject of study. The appearance of bedding under Fort Doyle described on p. 409, and there attributed with much hesitation to an inclusion of slaty rock, I am now able to recognize as the tongue of an intruding dyke in which pressure has produced the semblance of a slate.

Discussion.

The President remarked that the evidence as to the age of the Alderney gneisses was clear.

Prof. Bonney had never visited Alderney, though he was acquainted with the other Channel Islands, but he knew that it had received very great attention from Mr. Hill.

The age of these gneissoid rocks, which formed an uneven floor to the Lower Palæozoic Rocks, could be shown. At Omonville, near Cap La Hague, the "grès felspathique" rests on gneissoid rock. At Tourlaville, east of Cherbourg, green slates ("schistes de St. Lo") pass up into the "grès felspathique," which is overlain by the "grès Armoricain," perhaps unconformably. At Coutances gneissoid rock underlies the "schistes de St. Lo," which have a great development in Western Normandy. These gneissoid rocks, like that in the south of Guernsey, are doubtless crushed granites, which in some places, as at Alderney, are little modified. The strike of the structure is very roughly N. and S., that of the palæozoics about E. and W. There is no opportunity of bringing in crushing between early Cambrian and the end of the Lower Palæozoic, so that these gneissoid rocks must be Archæan. The "grès Armoricain" and the "grès felspathique" recall the quartzites of Northern Scotland and the Torridon Sandstone, and

the unevenness of the floor in this part of Europe is consequently similar to that of Northern Scotland.

Dr. Woodward referred to a supposed *Oldhamia*, and pointed out that the markings were due to the action of recent Limpets.

Dr. Hicks referred to the researches of M. Bigot, and commented upon his excellent work. The views put forward by Mr. Hill, like those of M. Bigot, seemed to confirm the Pre-Cambrian age of the rocks in Normandy and Brittany, originally determined as such by M. Hébert.

Mr. Rutley asked for further information as to the felsites of Boulay Bay, and especially with regard to their age.

Mr. Teall said that he had understood that the Boulay-Bay felsites must be Pre-Upper Cambrian, which brought them into apparent relationship with the very similar Wrekin rocks.

Mr. Cole commented on the wide bearing of the question of the age of these rhyolites. French geologists had maintained that the pyromerides containing quartz were of Silurian age; those of Permian age contained chalcedony, and those of more modern origin opal. The removal of the Boulay-Bay rocks from those of the Vosges was opposed to this mineralogical view.

The Author observed that the ancient floor of crushed rocks had not escaped his attention. Mr. Etheridge had observed that the simulations of fossils resembled markings of modern Mollusca. A great thickness of rhyolites occurred in Jersey, which was considered to be one series. Only certain varieties of these could be identified as pebbles in the sedimentary rocks. Among these pebbles he had not actually recognized pyromerides; but he quite agreed with the view that the age of the Boulay-Bay rocks was the age of the other rhyolites.

25. Note *on the* Pelvis *of* Ornithopsis. By Prof. H. G. Seeley, F.R.S., F.G.S. (Read March 20, 1889.)

In 1874, on the occasion of my first visit to Eyebury to examine the fossil reptiles of the Oxford Clay, Mr. Alfred N. Leeds, and Mr. Charles Leeds, M.A., mentioned to me the following circumstance. A well had been sunk at the gas-works at Peterborough, which, at the depth of 36 feet, came down upon a number of bones of a large terrestrial reptile. It is well known that to the west of Peterborough the Cornbrash and Lower Oolites rise from beneath the base of the Oxford Clay. The well passed through 24 feet of blue clay, which Mr. Leeds had no difficulty in recognizing by its fossils as typical Oxford Clay. Beneath the clay were 12 feet of grey sand, nearly white in places, and fine-grained, but it was uncertain whether the bedding which it showed was current-bedding. Beneath the sand were the bones resting on the underlying clay. Mr. Charles and Mr. Alfred N. Leeds were fully aware that the remainder of the skeleton was probably on the spot, and made overtures to the Gas Company to allow them to drive a horizontal shaft in the hope of finding it. The bones found remained exposed to the weather for some time till they began to crumble beyond recognition and ceased to be interesting, when they passed into the hands of the most enthusiastic and able explorers who have worked the Oxford Clay. These gentlemen had the bones still in the matrix when I first saw them in an outbuilding, and I was impressed by the grey sand as something to which I knew of no parallel on that geological horizon in that part of England. A large rib had been put together, as well as an ischium and part of a pubis; I also saw a part of the centrum of a dorsal vertebra. On these remains I formed and expressed the opinion that they were closely allied to, though probably not identical with, the large *Cetiosaurus* in the Oxford Museum. After an interval of eleven years I again had my attention directed to this specimen, when Mr. Charles Leeds wrote that he had determined the fossil to be *Ornithopsis*, on the basis of comparison with the Wealden specimens in the British Museum, and inviting me again to examine the remains. Being otherwise fully occupied and unable to leave London, I referred Mr. Leeds to Mr. Hulke as the author of nearly all that has been written on *Ornithopsis*; the result appeared in a memoir on *Ornithopsis Leedsii*, printed in the Quarterly Journal of the Geological Society.

These remains, still preserved in the wonderful collection at Eyebury, are the largest and most perfectly preserved pelvic bones of a Saurischian reptile known in this country. Their chief characters have been sufficiently, though briefly, given by Mr. Hulke, and I should not have added to that notice if it had not been that a new examination of the reptile has led me to take a divergent view of the mutual relations of the bones.

Sketches illustrating the Pelvic Characters of Species referred to Ornithopsis.

Fig. 1.—*Ornithopsis Hulkei.* (About $\frac{1}{18}$ nat. size.)

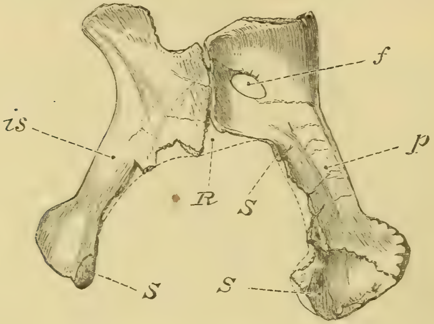


Fig. 2.—(*Ornithopsis*) *oxoniensis.* (About $\frac{1}{30}$ nat. size.)

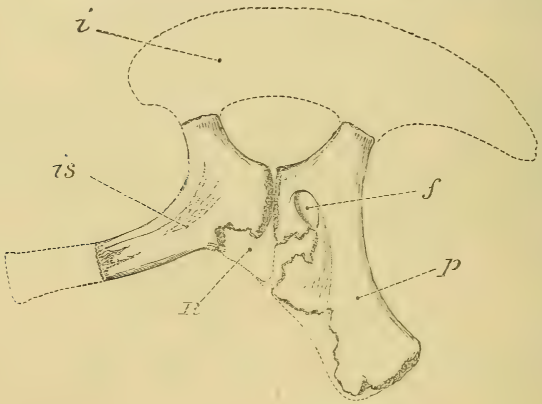
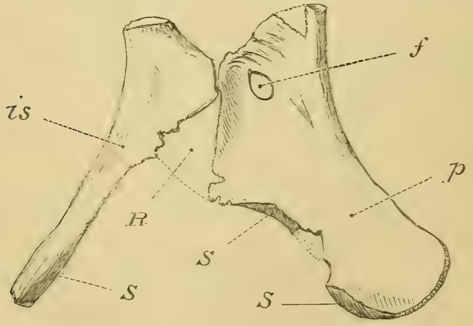


Fig. 3.—(*Ornithopsis*) *Leedsii.* (About $\frac{1}{18}$ nat. size.)



i, ilium; *is*, ischium; *p*, pubis; *f*, foramen.
R R, restorations; *S S*, sutural surfaces.

Mr. Hulke does not expressly determine these pelvic bones as right or left, and he is equally indefinite with regard to the remains of the Wealden *Ornithopsis*. Still the fact that Professor Marsh figured the external surface of the pelvis of *Atlantosaurus*, and that Mr. Hulke has copied that figure reversed in pl. xiv. Quart. Journ. Geol. Soc. vol. xxxviii. in illustration of what I regard as *Ornithopsis Hulkei*, is some evidence that the figured surface was regarded as external, and the bones as belonging to the right side of the skeleton *. However this may be, I had no doubt that the figured surface in *Ornithopsis Leedsii* is the internal or visceral surface, and therefore the bones are of the left side; and the Wealden specimen shows substantially the same characters. This difference in interpretation involves a totally different conception of the nature of the pelvis, and supposing the ilium to have been correctly determined, its chief extension may be varied, as I traced the sutural surface on the pubic bone which extends in the median line of the body of the animal. Mr. Alfred N. Leeds had the kindness to remove these massive specimens from their positions in his museum, so that the bones from the right and left sides of the body might be adapted to each other in the inclined positions which I regarded them as having occupied during the life of the animal. It then became manifest that the bones were united in the median line almost throughout their length by a median suture, and that they formed a saddle-shaped surface from front to back, as do the larger Plesiosaurs from the Oxford Clay.

The left pubis becomes thickened at its anterior extremity, which shows a cartilaginous surface; but internally there is a well-marked suture in the median line, which is bevelled at an angle of 45°. This articulation is six centimetres deep and about 24 centim. long, terminating posteriorly in a sharp point, where there is a small median foramen between the bones, with a well-ossified border. This suture ascends in level as it extends backwards. The internal surface of the pubis is flattened, and the external surface is convex transversely over this anterior portion of the bone. Behind this suture the bone is bent in an arch, so that its external surface is concave from front to back along the median line. On the inner margin the median sutural surface is prolonged for 25 centim., behind which the continuity of the bones is interrupted by a smooth border to a notch which may have separated the bones by 14 or 15 centim. In the middle, where it is strongest, this posterior part of the symphysis is 4 centim. in vertical depth. It is inclined to the internal surface, but to a less degree than the anterior part of the symphysis, consequent on the arched form bringing the hinder part of the pubic symphysis into a superior position, so that the bones of the two sides meet at a less acute angle. The two pubic bones are thus so inclined to each other as to enclose an anterior basin and a posterior basin, which are separated by the intervening saddle-shaped arch.

* Mr. Lydekker adopts this determination in the British Museum Catalogue, vol. i. p. 150, describing the bones as associated right ischium and pubis.

The suture with the ischium, which is nearly straight, may have been nearly vertical; it is 30 centim. long. The sutural surface becomes narrow as it descends, and the bone becomes thin towards the median line.

The ischium is curved in length, with the convexity on the inner side, and it is twisted at an angle of 45°, so that the superior distal surfaces are directed outward and upward, and the inferior margins converge and meet in a broad V shape. This union is assisted by the internal distal border of the bones being bevelled at an angle of 45° for a length of 30 centim., and this surface is marked with coarse parallel longitudinal sutural lines. Externally the distal extremity of the bone is thickened superiorly for 15 centim., as though for muscular attachment. The bone is imperfectly preserved, so that the larger part of the anterior sutural union with the pubis is broken away towards the median line of the body. At a distance of 43 centim. from the proximal end there is, on the internal border, a small portion of smooth ossified margin which is concave, and this I take to indicate the posterior termination of the proximal expansion of the bone. Externally the infra-acetabular surface is concavely excavated in the usual way. The sutural surface for the ilium is 15 centim. long; the acetabular interval between the ischium and pubis is 15 centim. wide, and the iliac attachment on the pubis is 19 centim. long, as preserved, and appears originally to have measured about 33 centim. The greatest thickness of the bone where it unites with the ilium is 5 centimetres. I am not aware that this type of pelvis has hitherto been observed. The antero-posterior arch between the anterior symphysis of the pubic bones and the posterior symphysis of the ischia is a well-marked characteristic of Saurischian reptiles; but it remains to be determined to what extent the median union of the pubic bones is developed in the group.

From the imperfect fragment preserved it is impossible to judge of the form of the ilium, but it does not make any recognizable approximation to the bone in those American genera which offer the closest resemblance of form to the pubis and ischium.

When the bones from the Oxford Clay are compared with those from the Wealden of the Isle of Wight there are several minor differences of proportion; but although the internal border of the Wealden pubis is badly preserved, its distal inner border shows an inclined symphysial suture, and a symphysial suture is present on the most convex part of the arch in the middle of the bone, which is more prominent than in the relatively wider, thicker bone of *Ornithopsis Leedsii*. In the Wealden specimen the obturator foramen in the pubis is relatively nearly twice as large as in the Oxford-clay specimen, and is more obliquely placed. The ischium in the Wealden specimen is relatively much broader and stronger than in the Oxford-clay fossil; it has a much wider iliac head, defined by a deep concave subacetabular notch, which is almost wanting in the other type; the distal end is expanded, and though its symphysis

is the same kind of oblique V-shaped union as in *Ornithopsis Leedsii*, it is very small and short, so that the bones did not converge towards each other in similar curves. The antero-posterior extension of these pelvic bones in the symphysial line appears to me to have been relatively greater in (*Ornithopsis*) *Leedsii* than in *Ornithopsis Hulkei*.

These species may be further compared with (*Ornithopsis*) *oxoniensis*. In relative proportions of the ischium and pubis the bones, as represented in Prof. Phillips's figure, closely correspond with the Oxford-clay species; for, though there is a comparatively long articular head to the pubis as well as the ischium (absent from the Isle-of-Wight fossil), the forms and proportions of both sets of Oolitic bones are otherwise respectively nearly identical, and these two species are apparently referable to one genus. It is, moreover, interesting that the ilium of (*O.*) *oxoniensis*, which has some resemblance to the ilium of *Brontosaurus*, appears to have been prolonged anteriorly in a wedge-shaped mass, and that the imperfectly preserved ilium of (*O.*) *Leedsii* appears to show a similar character. But the ilium of *Ornithopsis Hulkei* is not known, and the nearly equal size in that species of pubis and ischium, seem, with the other differences pointed out, to justify a suspension of judgment as to its generic identity with the closely allied fossils from older strata; for the slender ischia give a good character for generic separation when compared with the expanded ischium of *Ornithopsis Hulkei*.

At the Bath Meeting of the British Association Professor Marsh expressed the belief that *Ornithopsis* held a systematic position midway between *Morosaurus* and *Diplodocus*. I have unfortunately no means of forming an independent opinion. But Professor Marsh defines the shaft of the ischium in *Diplodocus* as not twisted, and states that it "is directed downward and backward with the ends meeting on the median line"*. I fail to recognize in the condition here represented any approximation to the description of *Diplodocus*. The description of *Morosaurus* seems to me closely to approximate to the Ornithopsoid reptiles from the Forest Marble and Oxford Clay, while there is much to be said in favour of the view of Mr. Hulke that *Ornithopsis Hulkei* approximates to *Atlantosaurus*. I hesitate to formulate the inference of generic distinction between these Wealden and Oolitic reptiles from these resemblances to American types until it is shown that the American genera all have the pubic bones united by a long median symphysis as in these British types, which probably belong to closely allied genera, although they may be more distinct from each other than are *Morosaurus* and *Atlantosaurus*. The nature of the relation between the three British types may be better gathered from the accompanying figures of the pelvic bones (p. 392).

After the bones of (*Ornithopsis*) *Leedsii* had been put together in their natural anatomical relations, Mr. Alfred N. Leeds made a model of them in pasteboard; and I now submit a slightly restored model of these bones, which I think serves to establish the generic

* American Journal of Science, vol. xxvii., Feb. 1884.

distinction of this type from the American genus *Morosaurus* *, and to show that *Brontosaurus* cannot be identified with it, although there is some resemblance to that genus in the ilium and pubis.

Discussion.

Mr. Lydekker observed that the identification by Prof. Seeley of the proper ventral and dorsal surfaces of the pelvis of *Ornithopsis* was of considerable importance, since it removed all objections which had been raised as to the close affinity between that form and the American *Brontosaurus*, &c., which he had always believed to be closely related.

He was unable, however, to assent to the amalgamation of *Cetiosaurus* and *Ornithopsis* which the Author appeared to suggest, the difference in the pelvis of the two forms indicating a character of at least generic value.

The speaker had already pointed out the resemblance of the pelvis of *Cetiosaurus oxoniensis* to that of *Morosaurus*, and he was glad to observe that Prof. Seeley agreed with him in this respect.

With regard to nomenclature, after alluding to his previous statement that he believed the name *Cetiosaurus* ought to yield to the earlier *Cardiodon*, Mr. Lydekker observed that he had two days ago received a letter from Dr. Baur, pointing out to him that the tooth from the Wealden originally figured by Dr. Wright had been named, in 1852, *Hoplosaurus* † *armatus*. The speaker had suggested that this tooth really belonged to *Ornithopsis*, and Prof. Seeley had regarded this suggestion as a certainty. Under this circumstance there was no question but that, if the two are really identical, the name *Ornithopsis* must yield place to the much earlier *Hoplosaurus*, even if the latter had not to give way to the still earlier *Pelorosaurus*. It was curious, after the complex synonymy, to find that both the Wealden *Hoplosaurus* (? *Ornithopsis*) and the Lower Jurassic *Cardiodon* (? *Cetiosaurus*) were both based on the evidence of teeth, and were therefore strictly comparable.

Mr. Leeds considered that Prof. Seeley had given the correct interpretation about these bones.

Prof. Seeley said his thanks were due to Mr. Alfred N. Leeds for the opportunity of clearing up the structure of the Saurischian pelvis. He was not aware that the structures now described had been previously recognized by any other observer. He had endeavoured in his paper to make it clear that while on the one hand

* Since writing the note on *Aristosuchus pusillus* (Quart. Journ. Geol. Soc. vol. xliii. May 1887) I have been led to notice that the position of the pelvic bones in relation to the sacrum gives grounds for suspecting that the bone there regarded as pubis is likely to be an ischium, notwithstanding its resemblance in form to the pubis in some American genera. Professor Marsh's figure of *Ceratosaurus* shows that the ischium may have an anterior symphysial expansion, like the posterior expansion of the pubis in that genus and other types. Whether *Aristosuchus* may have had cervical vertebræ like that which I provisionally referred to *Thecospondylus* (Quart. Journ. Geol. Soc., Feb. 1888) may deserve consideration.

† Originally *Oplosaurus*.

he did not follow Mr. Hulke in referring the three Saurischians to *Ornithopsis*, and while he offered a restoration of the pelvis of *Cetiosaurus oxoniensis* to illustrate its relation to the Oxford-clay and Wealden types, the grounds had been stated on which the Oxford and Peterborough animals might be referred to another genus, when the evidence was more fully set out. The affinity of *Cetiosaurus oxoniensis* to *Morosaurus* cannot be determined, because the distal end of the ischium is not preserved. Prof. Seeley regarded nomenclature as a matter of scientific convenience, and he was not prepared to give up names associated with the history of research in favour of an obscure name that was casually exhumed and introduced doubt in our interpretations.

26. *The* Elvans *and* Volcanic Rocks *of* Dartmoor.
By R. N. Worth, Esq., F.G.S. (Read April 3, 1889.)

In the course of an inquiry into the physical history of Dartmoor, which led to the conclusion that this great granitic upland represents the basal portion of a volcano some 16,000 feet high, special attention was necessarily paid to the felsites or elvans of the district, as filling the gap between the plutonic members of the series, the granites, and the true volcanic rocks no longer found *in situ*. Search for traces of the latter was also made. Hence were gathered the facts now briefly set forth. The less definite term "elvan" is used here in preference to the more distinct "felstone" or "quartz-" or "felspar-porphyry," because the intention is to include under that head all the dyke-rocks of granitoid material connected with the Dartmoor granite; and because it is one of the chief objects of this paper to show that there is no fundamental distinction between the rocks so named, as they occur in the Dartmoor environment, but that different portions of the same dyke may exhibit all these varieties of structure, and present a graduated series between granite and a compact felsite, in which differentiation has yet to be set up. An "elvan" may be any species of rock that has developed from a granitic magma under conditions intermediate between plutonic and volcanic.

One of the first points to attract attention in the inquiry was the great disproportion existing between the characteristic varieties of elvans to be found *in situ* (I am speaking generally of the south-western borders of Dartmoor) and those occurring in the detritus which covers large areas of bottom land in the border valleys of the Moor. Elvans, too, are far more largely represented in the latter than in the adjacent modern river-beds.

Tracing back the history of denudation, next came the allied fact that while granitoid pebbles are to be found in quantity on many of the beaches near the mouths of the rivers of Dartmoor origin, on the shores of the English Channel, there, again, elvans largely predominate. That these accumulations represent in the main an ancient as distinct from a modern denudation seems clear. For example, while in the beaches immediately within the mouth of the Yealm no such pebbles occur, on the beaches immediately outside they are plentiful. Mr. Pengelly, F.R.S., has described similar phenomena at the mouth of the Erme*. Granitoid pebbles abound in a cove close to the mouth of that river; but for two and a half miles upward thence Mr. Pengelly failed to detect any granitoid rocks on the course of the Erme. The conclusion that these pebbles were not brought down by the rivers, "but cast up by the sea," seemed therefore a natural one. So far as my experience goes, however, these pebbles are quite as clearly of Dartmoor origin as those of the old valley-detritus; and whether they were brought to the shore in

* Trans. Dev. Association, xi. pp. 329–30.

connexion with the present river-system or not, I have no hesitation in giving the great bulk of them, at least, a Dartmoor birthplace.

Some of these pebbles, found on Slapton Sands, suggested a possible secondary origin in the degradation of the Triassic conglomerate which extends westward in mass to Torbay, and remnants of a still further extension of which are to be found at Thurlestone in Bigbury Bay, and at Cawsand in Plymouth Sound. This led to an examination of a number of the fragments of igneous rocks included in the Triassic conglomerates of Devon. Among these indubitable pieces of Dartmoor granite have been from time to time identified, but far less numerous in comparison than the examples of so-called "porphyritic trap," with which they are largely associated. The results of that examination speedily convinced me that many of these "porphyritic traps" were really "elvans," whilst others presented a nearer approach to volcanic types. Probably this would have been recognized long since had there not been a kind of tacit assumption that the covering rocks under which the granite of Dartmoor consolidated were wholly sedimentary. Had the volcanic character of at least the central pile been suggested, it would have been clear that in such an early stage of denudation as that which afforded material for the Triassic conglomerates of Devon, rocks of intermediate and volcanic types must play a far more prominent part than granites.

It is evident that the "felsites" of the higher stage of Dartmoor must have been much more important and wide-spread than the "elvans" or dyke-rocks by which they are now alone represented, or they never could have yielded the enormous quantity of material which is still traceable.

The "elvans" which remain *in situ* are practically confined to the borders of the moorland, ranging at points up to the main mass of granite in the covering rocks, and stretching westward in parallel lines towards the next granitic boss, on the western side of the Tamar, at Hingston Down. Five of these dykes are set out on the Geological Map of Devon between Shillamill near Tavistock, on the north, and Cann Quarry near Plymouth, on the south; there are others, but of minor importance and yielding no additional facts.

Now the northern of these elvans traverse the lowest rocks exposed in this area, and the southern the highest; moreover the northern are nearest to the main mass of granite, and the southern most distant from it. The northern, therefore, have been formed, to all appearance, under conditions of greater depth and pressure than their successors southward. As a result of this, we find the most distinctly granitoid or plutonic varieties in the northern elvans, Shillamill and Grenofen, and the most even-grained and felsitic in the southern at Cann Quarry; while the Roborough Down elvan, which is intermediate, to some extent, combines the two characteristics, in its compact felsitic ground-mass and its well-developed porphyritic quartz-crystals.

But the chief point to which I wish to direct attention here is the wide amount of variation within narrow limits in the same dyke.

Some of the characteristics of the Shillamill elvan are set forth by Mr. Rutley, in his 'Eruptive Rocks of Brent Tor'*; but a far finer section than that exposed at the time of his visit has recently been opened across the dyke in the construction of the new London and South-Western extension, and I do not know of any spot where extreme features of elvanic variation can now be studied to better advantage. The centre of the dyke is, to quote Mr. Rutley's words, "a quartzose felspar-porphyry of the usual elvanitic type;" but on each margin the rock is dark grey, in part granular in texture, in part massive, and with unevenly distributed dots and patches of dark greenish hue. Some parts, again, would fall under the old name of "claystone-porphyry." The different phases graduate into each other, but it would be easy to select what, on a mere casual survey, might be taken to represent half a dozen different rocks from half a dozen distinct localities. Mr. Rutley notes that while the three sections which he describes "are identical in their original composition, yet they differ greatly in their general aspect;" and this is emphasized by the results of my examination of sections from this new exposure.

Microscopic investigation shows that while the leading constituents are, as Mr. Rutley says, orthoclase, quartz, and magnesian mica, with a varying amount of felsitic matter, and that the porphyritic felspars have been much decomposed, there is also present in portions of the dyke a considerable proportion of dark-green hornblende, chiefly associated with the more definite quartz and felspar. The occurrence of hornblende is so unusual in the Dartmoor granites and granitoid rocks that this is especially noteworthy. The proportion of felsitic matter varies greatly in different portions of the dyke, and some parts are distinctly granular. As accessories there occur casually iron and copper pyrites and some chlorite. This elvan has been the subject of great alteration, and there is hardly any that will better repay careful study.

The other elvan that claims special mention is the Grenofen, which is half a mile south of the Shillamill, and stretches from east to west four miles. Mr. Rutley observed this at the Lower Grenofen quarry, where it has a well-marked porphyritic character, and contains so little felsitic matter that it is essentially a fine-grained porphyritic granite, partially syenitic, seeing that hornblende is irregularly developed.

This elvan, unlike the Shillamill, retains its general characteristics in breadth, but varies greatly in its length. It has recently been intersected in a tunnel on the new railway not far from Shillamill, and is there essentially an even-grained, loose-textured granite, the kaolinization of the felspar having proceeded so far as to make the rock quite rotten. Still further west, about a mile distant, on Morwell Down, the dyke yields a variety with a compact semi-vitreous ground-mass, in which felspar, quartz, and mica are porphyritically developed. Under the microscope the felsitic base is seen to be remarkably even-textured, resembling ground glass, and

* Pp. 24, 41, 42.

the porphyritic crystals singularly perfect in outline and character. Though it is not an andesite, andesitic affinities seem to be suggested.

As it is simply intended to indicate the more typical features of the "elvans," and those of Grenofen and Shillamill surpass all others in interest, I pass on to consider the evidence afforded by Dartmoor of the existence of distinctly volcanic rocks as a part of its igneous series.

There are among the fragments of the local Triassic conglomerate examples of andesitic and similar rocks that may fairly be classed in this category, but I do not desire to lay any special stress upon them.

It is more distinctly to the point that in October of last year there was found in undisturbed clay on the limestone of Cattedown, near Plymouth, a deposit of water-borne and water-worn detritus, which indicated a Dartmoor origin for a large proportion of its identifiable constituents, but contained associated therewith rolled flints and pebbles of Carboniferous, Liassic, and Cretaceous limestones, which could not have been brought to the place where they were found from any existing locality by any existing river. The inference seemed clear that these Carboniferous, Liassic, and Cretaceous remnants represented a very ancient denudation, when the western flanks of Dartmoor were partially covered by Carboniferous rocks which have now disappeared; by the Chalk, of which the nearest trace is now on Haldon; and by the Lias, which does not now extend further west than Lyme Regis.

And associated with these clearly identifiable and undoubtedly local rocks were others hitherto unknown in the West—examples of andesites which Professor Bonney has kindly examined for me, and has pronounced typical examples, closely resembling specimens from the Andes; and clastic igneous rocks, one of which, a volcanic grit, Professor Bonney regards as of very unusual interest, and as the result of the denudation of volcanic cones. Some of the fragments are felspar, but quartz and viridite also occur. Prof. Bonney remarks that the rock-fragments, so far as ascertained, are all of igneous origin. "Some are fairly clear, some a rich brown colour, some almost black with opacite; some are homogeneous, except for a little opacite and some belonites or trichites of a dark grey colour, which often are grouped in more or less dendritic forms or bundles like rootlets. A few of these grains are still isotropic, but most of those which are transparent exhibit devitrification-structure. Small spherulites are rather common; one fragment seems part of a large spherulite. Other fragments show flow-structure; one is perlitic. Clearly several varieties of rock are present, but I think the majority may be referred to andesites, some of which may not be far removed from basalt; others may have a tolerably high percentage of silica."

I believe I am perfectly safe in saying that there are no rocks in the county or in the West of England yet known that would yield either of these andesites or volcanic fragmental examples. If they belonged to the superstructure of Dartmoor, the denudation of which began in Triassic times, the absence of the parent-rocks is explained.

If they did not belong to Dartmoor, their association with rocks all of Dartmoor origin, assured or probable, has to be accounted for. And that enormous changes have taken place on the moor since the existing river-systems have been in operation, the deep gorges cut by the principal streams, and the fact that I have recently found remnants of an ancient Dartmoor river-gravel 300 feet above the present bed of the Tavy, near Tavistock, will attest.

However, the point need not be left to inference only. Among the specimens collected by me from the Dartmoor detritus at Lee Moor, within the granitic boundary, was a piece of compact grey felsitic rock which indicated fluxion-structure. This, on being sliced, proved to be a felsitic lava-breccia, containing numerous fragmental grains of quartz and also fragments of volcanic rock, some of which closely resemble certain fragments in the volcanic grit of Cattedown.

That the forces which upheaved the great granitic boss of Dartmoor found relief in a volcanic outburst seems therefore clear, though not a vestige of the volcanic pile remains.

The purpose of this paper is threefold:—

1. To give reasons for the belief that the present granite of Dartmoor passed upwards into felsitic and volcanic rocks, remnants of which are to be found in the Triassic conglomerate of Devon, in the detritus of the bottom lands of the moor itself, on the beaches of the Channel, and in ancient river-gravels and pebble-beds.

2. To indicate the wide range of character taken by the Devonian felsites of the Dartmoor district.

3. To point out some of the evidence that exists in the elvans *in situ* for the development of the most varied of their forms from one common magma, and the peculiar value of their study as bearing upon the wider questions of petrological research.

Discussion.

Prof. Bonney stated that the specimen of volcanic grit which he had examined for Mr. Worth was one of the most extraordinary samples ever sent to him. He agreed with the Author as to the importance of studying the Triassic conglomerates of the south-west. The term "elvan" should not be used as a scientific term, having been so vaguely applied.

Dr. Hinde called attention to the absence of specimens on the table as a check upon discussion.

27. *The* Occurrence *of* Colloid Silica *in the* Lower Chalk *of* Berkshire *and* Wiltshire. By A. J. Jukes-Browne, Esq., F.G.S. *and* W. Hill, Esq., F.G.S. (Read March 20, 1889.)

The existence in the Lower Chalk of beds containing a certain proportion of pure disseminated silica is not a new discovery, the occurrence of such material having been proved by Messrs. Way and Paine in 1851 *; but we are not aware that it has ever before been found in such quantity, or that any detailed investigation of its mode of occurrence has previously been made.

The beds which are the subject of the present communication were discovered during the examination of the Lower Chalk of Berkshire and Wiltshire in 1887–88, for the purposes of the Geological Survey, and we are indebted to the Director-General of the Survey for permission to make use of the stratigraphical information then obtained. Beds of siliceous chalk were first observed near Wantage and Letcombe Bassett, and attracted attention from their hard and compact character; they occurred near the horizon at which the Totternhoe Stone is found further north, and it was at first thought possible that one of them might be the representative of that stone. Specimens were therefore submitted to microscopical examination, and were found to be different from Totternhoe Stone and from any other samples of Lower Chalk previously examined by us. The exact stratigraphical position of these beds was subsequently ascertained by means of the excellent section exposed by the cutting on the Didcot, Newbury, and Winchester line, near Chilton. This section we visited together, and the hard siliceous beds were found to occur in the upper part of the Chalk Marl or zone of *Ammonites varians*, a little way below the horizon of the Totternhoe Stone, of which a thin representative is seen in the cutting.

The following is the succession seen in the cutting about half a mile east of Chilton:—

		ft.	in.
Grey Chalk.	Grey bedded chalk, soft below, harder above	12	0
	Hard grey rocky chalk	1	0
	Hard grey bedded chalk with partings of marly chalk	5	0
	Dark grey gritty stone with many small phosphatic nodules (Totternhoe Stone)	2	0
Chalk Marl.	Soft grey marl, breaking conchoidally	5	0
	Hard compact siliceous limestone	1	3
	Soft shaly chalk	0	6
	Hard grey siliceous chalk	0	9
	Loose grey marly chalk	3	0
	Hard rough grey chalk	0	6
	Loose grey marly chalk	2	0
	Passing down into rather hard blocky chalk	3	0
		36	0

* See Journ. Roy. Agric. Soc. xii. p. 544.

The dip is southerly at a low angle, except at one place where there is a steeper inclination of 4 or 5 degrees for a short distance.

In the next cutting to the north two hard beds occur near the top, which may be the two lowermost seen in the former cutting, and they are underlain by about 20 feet of firm blocky chalk, with the fossils of the Chalk Marl. *Ammonites varians* is common throughout, and the following are not uncommon:—*Amm. Mantelli*, *Turrilites Scheuchzerianus*, *Inoceramus latus*, and *Rhynchonella Grasiana*.

All the courses described as "hard chalk" in the above sections are decidedly hard and weather out as conspicuous bands along the face of the cuttings; the highest course, however, is harder than the others, it rings under the hammer and only breaks under a blow of considerable force. The broken surfaces of the hard beds exhibit sparkling particles, some of which may be small flakes of mica, but other more minute points are possibly the broken ends of sponge-spicules. Recognizable sponge-remains are common throughout the whole set of beds, but seldom in a condition that allows of specific determination.

Similar courses of hard chalk, probably in all cases siliceous, occur in the same stratigraphical position throughout the range of the Berkshire outcrop. They may be seen in the cutting on the Great Western Railway at Moulsford Station, in a deep lane near East Ginge, above Wantage, and in road-cuttings at Letcombe Bassett.

In the neighbourhood of Calne and Devizes (Wilts) the Lower Chalk also contains beds of similar composition. This division of the Chalk is here unusually thick (up to 240 feet), and contains many hard rocky beds, especially in the upper part; but nothing exactly like the Totternhoe Stone has yet been discovered, so that we cannot say how much of this Chalk is the equivalent of the Chalk Marl. There are no large quarries in this part of the Chalk, and the most continuous exposures are along the bye-roads, which have been cut more or less into the rock along the hill-slopes, the harder beds often making a succession of small steps or ridges across such roads.

The hardest and most definite rock-beds occur in the upper half of the Lower Chalk, but none of these are highly siliceous; of soft Chalk Marl there is very little in Wiltshire, not more than 10 feet at the base, all the rock above this being of a firm and bedded or blocky nature, while certain portions of it, hardly distinguishable from the rest in general appearance, are highly charged with silica.

A good section of the lowest beds may be found to the east of Compton Bassett, near Calne, where a pit and a road-cutting show about 50 feet of the firm chalk resting upon 10 feet of soft Chalk Marl. Several beds harder than the rest stand out in the road-cutting and are more or less siliceous.

Silica, however, appears to be most abundant in the central part of the Lower Chalk from 100 to 120 feet above the base. On Etchilhampton Hill, east of Devizes, there is a small pit about 100 feet above the base-line, which exposes flaggy greyish-white chalk (5 feet)

overlying a bed of rather hard greyish chalk, which has somewhat the appearance of Totternhoe Stone. Examination by hand-lens shows that both are full of minute glauconite grains, and also present many minute sparkling specks which seem to have too great a brilliancy for mica. No siliceous nodules, however, occur here.

Near Allington, north-east of Devizes, the Lower Chalk appears to be about 240 feet thick, and an almost continuous exposure of the upper part may be found along the cart-road that leads northward up to the Downs. Firm white chalk is seen just above the 500 feet contour, and about 50 or 60 feet higher a set of hard beds makes a succession of ridges across the roadway: there are five or six of them, and the highest is not more than 40 feet below the Melbourn Rock, which crosses the road at an elevation of about 650 feet. This topmost hard bed is a compact heavy grey chalk with numerous black or dark green grains, characters which are very unusual at so high a horizon in the Chalk.

A still more interesting exposure occurs on the road leading up the hill, east of Eastcott, near Market Lavington. This we judge to be about halfway between the base-line and the horizon of the Melbourn Rock, and therefore about 120 feet above the former. About 10 feet of flaggy whitish chalk is here seen, and one of the beds contains many definite siliceous concretions of irregular shapes comparable to nodules of flint or chert, but unlike such nodules in being so closely united with the surrounding matrix that they are not readily separated from it. They are very hard. When broken they are seen to be of a yellowish or bluish-grey colour, with a dull earthy fracture, which is quite different from that of flint. Examined with a lens the fractured surface is seen to be rough and granular, and has somewhat the appearance of a piece of grey chalk which has been hardened by an infiltration of gum or cement. The nodules occur only through a depth of 12 or 18 inches of the chalk; and about 4 feet above this bed, the chalk becomes greyish and harder, but is still siliceous.

Higher up the road and at distances of about 80 and 40 feet respectively, below the Melbourn Rock, there are two very hard courses of grey chalk, the lower about 2 feet and the higher about 3 feet thick. The lowest of these occupies the position of the Totternhoe Stone, but is much more compact and does not contain any of the small phosphatic nodules which always occur in that stone; the upper bed has a rather coarser grain and more gritty appearance.

It is interesting also to note that these hard beds containing silica and sponge-remains set in concurrently with a decided increase in the thickness of the Lower Chalk. Throughout the counties of Cambridge, Bedford, Hertford, Buckingham, and Oxford the thickness of the Lower Chalk, wherever it can be measured, ranges between 150 and 170 feet; the thickness of the beds below the Totternhoe Stone, usually known as Chalk Marl, being generally about 70 feet. In Berkshire this lower division suddenly increases to about 140 feet; the Totternhoe Stone is very thin, and the overlying

Chalk is about 60 feet thick, making a total of about 220 feet for the Lower Chalk as a whole.

This thickness appears to be maintained all along the Berkshire outcrop and to increase slightly in Wiltshire. Whether there is anything more than an accidental connexion between the incoming of these siliceous beds and the thickening of the Lower Chalk is a question that must remain for future inquiry; we content ourselves here with pointing out the coincidence.

Microscopical Characters.

Before entering upon a detailed description of the minute structure of the rock-beds found in the sections above mentioned, we may premise that they closely resemble some of the sponge-beds which have been described by Dr. G. J. Hinde, F.R.S. *, more especially some varieties of the malmstones which form part of the so-called Upper Greensand of Surrey, Hampshire, and Berkshire.

Dr. Hinde's Memoir contains so much information and has been so useful to us in studying these sponge-beds of the Lower Chalk that it will be desirable to give a brief *résumé* of his observations for comparison with our own results. The Malmstones of Surrey and Hampshire are described as consisting of a siliceous or siliceo-calcareous matrix which encloses fragments of sponge-spicules, grains and rods of glauconite, and minute scales of silvery mica. The proportion of silica varies greatly: sometimes the rock is wholly siliceous, as at Farnham, when it is very light and porous; sometimes it is largely calcareous and becomes proportionately compact and heavy, as at Selborne; occasionally, as at Godstone, the rock contains nodules of bluish chert arranged in lines like flints in the Chalk, but not separating easily from the rock-mass.

In the more siliceous malmstones fragments of siliceous sponge-spicules are abundant, but less so than the minute hollow cavities or casts of spicules which interpenetrate the rock, and to the existence of which its porosity is due. In the more calcareous beds many of the spicules are replaced by calcite.

The siliceous spicules consist generally of amorphous, not crystalline or chalcedonic, silica. This amorphous or colloid silica, when viewed under the microscope by reflected light, has a milky-white or opal-like appearance. Mounted in Canada balsam and seen by transmitted light some spicules exhibit a distinctly granular texture, while others are only traversed in all directions by minute lines which can be resolved into incomplete elliptical rings. The spicular walls are neutral to polarized light and consist, therefore, of colloid silica, though this is not in the hyaline condition of modern sponge-spicules. The spicular canals are always filled either with chalcedonic silica, or glauconite or some other silicate, and these canal-casts often remain in the space from which the spicules themselves have been removed.

Besides the sponge-spicules there is an abundance of silica dis-

* Phil. Trans. Roy. Soc. 1885, pt. ii. p. 403.

tributed through the matrix of the malmstone, and in some cases almost entirely composing that matrix. This silica is also in a colloid condition, being quite neutral between crossed nicols, and it occurs either in the form of minute granules similar to those seen in the spicules or else in a globular form, "that is to say, in very minute bodies with circular outlines though not strictly of spherical form."

Describing this globular silica, Dr. Hinde says, "the globular bodies are either single and quite free, or in groups of two, three, or several individuals united together. The single globules present well-defined circular outlines; the individuals forming the groups are also circular, except where, in contact, they partially coalesce, and their margins become abruptly truncated. . . . When magnified about 500 diameters they present well-marked variations. In the commonest forms there is a marginal ring, about one sixth the diameter of the globule, which seems to be faintly striate, while the central portion has a granular appearance. In another form the surface is covered with faint striæ which radiate from an indefinite central granule. . . . . The very smallest and simplest globules consist of perfectly clear silica without striæ or granules." In size they vary from ·0014 millim. to ·045 millim. They dissolve readily in heated caustic potash.

Finally, Dr. Hinde remarks that "the presence in the same beds of silica in an amorphous condition, with the siliceous spicules in a similar state, taken in connection with the fact that the beds are filled with empty spicular casts from which the spicules have been dissolved . . . . points to the conclusion that the colloidal silica in the beds has been directly derived from the breaking-up and dissolution of the sponge-remains." He also observes that sedimentary deposits consisting in part of colloidal silica in a globular form seem to be of rare occurrence, and that he had not been able to find any previous notice of such. He is unable to explain the causes which have produced this singular form of colloid silica or to say why the silica of the sponge-spicules should not have passed into the more stable condition of chalcedony or crystalline quartz, as is the case with those of most other fossil sponge-beds.

With regard to the bluish nodular concretions found in the malmstone, he represents a section of one (pl. 40. fig. 2) as exhibiting numerous spicules in a siliceo-calcareous matrix, and he states that the minute globules of silica which are free or but lightly aggregated together in the friable portions of the rock, are in the nodules enclosed by transparent chalcedonic silica and seem to be gradually passing into the crypto-crystalline condition.

Coming now to the beds which form the subject of the present paper, it will be convenient to begin with the lowest horizon, and describe a specimen from the cutting some 250 yards south-west of Upton Station from what seemed a rather harder course than usual, about 70 feet above the base of the Chalk Marl.

Upton.—A thin section of this, viewed under the microscope,

showed the material to be such as is usual in the Chalk Marl, viz. a large proportion of amorphous calcareous material with shelly fragments, Foraminiferal cells, and grains of glauconite and quartz scattered abundantly throughout.

But there were also many traces of sponge-structure, a fact in itself somewhat remarkable; for in a large series of specimens of Chalk Marl to the eastward the occurrence of sponge-spicules in abundance is exceptional. These sponge-remains were, first, the shadowy outlines of scattered spicules, and, second, a section of the spicular mesh of a Hexactinellid * sponge, the outline of which was fairly well defined and the spicular canals faintly visible.

The material of the scattered spicules had a finely granular appearance, its nature being hardly determinable in the sections; that of the Hexactinellid appeared to be silica in the colloid condition, which presented partly a confused granular structure and partly that of the incomplete rings, as described by Dr. Hinde; with polarized light the result was negative. Treating a portion of this specimen with hydrochloric acid a brisk effervescence ensued, the whole being reduced to powder. The residue proved to be fine structureless material, quartz-sand, grains and rod-like fragments of glauconite, detached spicules of the Monactinellid and Tetractinellid type, and fragments of the spicular mesh of a Hexactinellid sponge.

Further examination of the spicular remains showed them to be in a condition similar to those of the malmstone described by Dr. Hinde. Viewed by reflected light, they appear white and smooth. By transmitted light they present a granular appearance, their outline seems irregularly broken, and the impression created is that of a slightly rough exterior; their spicular walls remained neutral with polarized light. Their canals are in almost all cases empty, and air-bubbles can be seen following their ramifications; but the rod-like fragments of glauconite seen in the residue after treatment of the marl with acid testify that in some cases the spicular canal is filled with this mineral.

Placing the residue of this specimen of the marl in a strong solution of caustic potash and maintaining a heat of about 160° or 170° for 40 minutes, the whole of the free spicules disappeared. But the result was different in the case of the Hexactinellid mesh. Examining a portion of this from time to time, the granular appearance slowly disappeared, and at the end of 40 minutes the mesh, when mounted in Canada balsam, while still retaining its form, appeared nearly translucent; viewed with polarized light the silica now remaining seemed to be wholly chalcedonic.

Dr. Hinde, who has very kindly examined this and many other of our specimens, writes, "solution seems only to have taken place in the nodes of the mesh which are now in places occupied by air-bubbles." The mesh, therefore, consisted partly of colloid and partly of chalcedonic silica.

It appears to us that in this particular specimen of the Chalk

* This is the only specimen of Chalk Marl we have examined which contains the mesh of a Hexactinellid sponge.

Marl the silica is for the most part retained in the spicules. In examining the sections of Marl it is not always easy to determine whether the material of which the spicules now consist is silica or calcite; but the greater abundance of free spicules found in the residue of this specimen after treatment with acid and the absence of colloid silica in globular form leads us to think a large proportion of them remain siliceous and have not calcareous casts.

Chilton.—Specimens of the Chalk Marl taken from the hard beds shown in the railway-cutting near Chilton, each at a slightly higher horizon, give somewhat different results.

Viewed in thin sections all show the presence of sponge-spicules, these being more clearly defined and more abundant in the uppermost of five beds examined.

The silica of the spicules can here be seen to be replaced by calcite, though in some cases it still remains in the colloid state, negative to polarized light. Incomplete elliptical rings can be sometimes perceived traversing the material of the large spicules, and glauconite often fills the spicular canal.

Treating these specimens with acid, a moderate reaction ensued; but the material did not break up to powder, and even after the acid had removed the calcareous matter pressure was necessary to break even small lumps.

Examination of the residue showed that comparatively few of the spicules retained their silica, the greater part of them having been destroyed by the acid, and only a few of Monactinellid and Tetractinellid types remaining. In these the silica preserved the characters already described.

In the finer part of the residue colloid silica in the globular form existed in considerable quantities. The globules correspond very closely with those described by Dr. Hinde, have circular outlines, and occur singly, or in groups, or in linear series, their outline being broken at the point of contact. They are, however, smaller than those of the greensands and malm, their diameter being about ·0006 of an inch, and their outline is less even and regular. Some appear to be discs with greater or less convexity, others are certainly spherical, the majority have a nuclear spot; but in these we have been unable to detect any radiate striation. Small masses of the globules have a brownish tint. All globules and spicules dissolved readily in heated caustic potash and are neutral with polarized light.

Sponge-remains were most abundant in the higher bed about 6 feet below the Totternhoe Stone, and it is here that the condition of the spicules can be most conveniently examined. Crystalline calcite can be seen to have replaced the silica of many spicules, but in others it still remains in the amorphous or colloid state.

With the increase in the number of spicules in this bed the amount of colloid silica in globular form increases also. It can be seen in thin sections dispersed through the matrix and also filling the cells of Foraminifera, the calcareous tests of which still remain.

It is impossible, by microscopic examination, to estimate accu-

rately the quantity of silica in the globular form which is disseminated through the marl; but we believe it forms a much larger proportion of the bulk of the material than chemical analysis would lead one to suppose.

As already stated, we have also found disseminated colloid silica in considerable quantities in the Chalk Marl of Wiltshire. The amount varies in different specimens, and in some cases the globules are exceedingly minute.

In all specimens examined spicules of sponges were present, in some only sparingly, in others they were more abundant. Usually they are rather small and thread-like, and appear merely as shadowy outlines in the matrix of the marl, but here and there in thin sections spicules can be clearly seen; in some the silica remains in the amorphous or colloid condition, in others it is clearly replaced by calcite. Siliceous spicules and rods of glauconite, the casts of the spicular canals, may also be found in the residue of the marl after treatment with acid.

Compton Basset.—Sponge, spicules are numerous in a hard bed 40 feet above the Chloritic Marl. In this the silica of many spicules can be seen to be replaced by calcite. Much colloid silica, in globules rarely exceeding ·0005 of an inch in diameter, occurred in the residue after treatment with acid. As in the Chilton specimens their outline is not so even as in those of the Malmstone; but in most other respects they are precisely similar, occurring in linear series, in groups and larger aggregations, or singly. Some still remain attached to the rods of glauconite which once filled the spicular canals.

Colloid silica also appears to be present in a specimen of the marl taken 60 feet above the Chloritic Marl at Compton. In this case its form can hardly be termed globular. A large part of the finer residue, after treatment with acid, consists of aggregations of minute but defined particles of irregular shape, amongst which a few well-formed globules occur. The material seems to be of the same nature as the globules, it is neutral with polarized light and dissolves readily in caustic potash.

Stockley.—This is a small place about 4 miles north of Devizes, and the pit where our specimen was taken is on the slope of the hill a very little way, probably not more than 20 feet, above the base of the Chalk Marl. The specimen is more marly and less hard than is usual in beds which we have found to contain much colloid silica. Well-defined sponge-spicules are seen to be fairly common in thin sections. Calcite has replaced the silica in some of them, in others it is in the amorphous or colloid condition. Rods of glauconite, which appear to have been the casts of the spicular canals, may also be seen in the sections, the walls of the spicules having disappeared entirely. The material does not break up on treatment with acid, and colloid silica in well-marked globules occurs abundantly in the residue. This is the lowest horizon at which we have found disseminated silica.

Allington.—A specimen of marl 140 feet below the Melbourn Rock contains but few spicules, and siliceous globules occur only sparingly in the residue. About 80 feet below the Melbourn Rock at Allington is a bed of hard Chalk Marl in which spicules occur. Treatment with acid easily reduced the material to powder, the residue consisting of quartz-sand, a few siliceous spicules, &c., and a large proportion of flocculent matter. This, when dried, mounted in Canada Balsam, and viewed with a power magnifying 200 diameters, appeared full of specks, but otherwise structureless; entangled in it were minute particles of quartz. When magnified 640 diameters many of the specks could be resolved into minute discs rarely more than ·0002 inch in diameter, bearing a strong resemblance to the globules of colloid silica. As a rule these minute discs are single, but groups of three and four can be seen. Their outline appears generally circular, but not always so; like the larger globules they are neutral to polarized light and easily destroyed in caustic potash.

In a hard bed 40 feet below the Melbourn Rock at Allington, the highest well-defined bed in the Lower Chalk of this district, sponge-spicules are seen sparingly. Their condition appears to be as usual, some being siliceous, while in others the silica is replaced by crystalline calcite. This bed contains a large proportion of coarse shelly fragments, chiefly *Inoceramus*-prisms, reminding one of the Totternhoe Stone. Scarcely any globules of colloid silica occur in the residue, but a large proportion of the *Inoceramus*-prisms are completely silicified and are unaffected by acid; immersion for 30 minutes in a heated solution of caustic potash likewise appeared to have no effect on them.

Etchilhampton Hill.—Two specimens of Chalk Marl were taken from a pit on this hill about 100 feet above the Chloritic Marl. The chalk here contains a large proportion of smallish shell-fragments, none of which are silicified. The specimen from the base of the pit contains but few spicules and little colloid silica; but in that from the upper part colloid silica in well-marked globules or aggregations of them occurs plentifully. Sponge-spicules can be seen in thin sections of this specimen, but they are not well defined; calcite appears to replace the silica in most of them; a few spicules with their silica in the amorphous condition were found in the residue after treatment with acid.

Eastcott.—Sections of the Chalk Marl from various parts of the whitish friable chalk in which the chert-like nodules occur at Eastcott show that it does not differ materially from the marl of the district. Sponge-spicules are common, though not abundant, and are seen perhaps more distinctly than usual. The greater part of them are fine and thread-like, and in these the silica seems to be replaced by calcite; but in the larger ones it is chiefly in the amorphous or colloid condition.

In none does the silica appear chalcedonic. The material will not break up on treatment with acid, and the finer part of the residue consists almost entirely of colloid silica in globules or aggre-

gations of them. These globules are smaller and less even in their outline than those of the Malmstone, but are identical with those of the upper bed in the Chilton cutting. The marl immediately surrounding the chert-like nodules shows no difference in its character; but the globules of colloid silica are distinctly larger and more closely resemble those of the Malmstone.

The material of the nodules themselves is the same as the surrounding marl. Grains of glauconite and quartz together with Foraminifera and fragments of shells are scattered through the mass just as they are through the surrounding chalk, from which it only differs in the presence of the chalcedonic silica, which appears to permeate and partially replace the calcareous material. That some calcareous matter remains is proved by effervescence when a piece is placed in acid; but the action is much less brisk than in the case of the surrounding material, and shows that the amount of calcareous matter in the chert is small. Sponge-spicules are abundant, many are of the type found throughout the marl, fine and thread-like in form; but others occur much larger in size. In the greater number of them the silica is either wholly or in part in the condition of transparent chalcedony, and chalcedonic silica also fills cavities which appear to have been produced by the decay of organic fragments other than spicules, and also the interior of the cells of Foraminifera, which yet retain their calcareous tests.

There are spicules, however, with their silica still in the amorphous or colloid state, and the sections of the nodules exhibit remarkably well the various changes in their condition.

Colloid silica in globular form is very abundant, the globules being in all respects similar to those of the Malmstone and Greensands described by Dr. Hinde. Globules are especially abundant in the vicinity of sponge-spicules and may be seen filling the spicular canals even where the walls are of transparent chalcedony. In fact they frequently appear surrounded by chalcedonic silica, and it is difficult to say whether they are or are not "chalcedonified;" but after the action of acid and heated caustic potash we have been unable to detect a single free globule of chalcedonic silica, and only those remain which appear to have been protected by the surrounding chalcedonic material. Spicules treated for 30 minutes in heated caustic potash present a rugged and uneven outline, showing that the silica is not completely crystalline.

It is interesting also to find that the constitution of the hard siliceous nodules in this chalk is similar to that of the nodules which occur in the Malmstone. Dr. Hinde, in a letter to one of us, says "the portion of the chert-like nodule closely resembles the bluish nodules which occur in the Malm or Upper Greensand of Merstham and Godstone, which are locally known as flints; and the sections from them likewise correspond to a great extent with those I have from the Merstham nodules, save that in your specimens the minute siliceous discs or globules of colloid silica are less abundant and seem to have been converted into transparent chalcedony. . . . The silica is partly amorphous and partly chalcedonic;

and the gradual change from the amorphous to the chalcedonic condition is very distinctly visible."

Dr. Hinde thinks that the nodules can hardly be correctly termed chert, because the silica of ordinary chert is entirely chalcedonic, whereas our specimens have an admixture of amorphous silica and of amorphous calcareous matter, so as to be really calcareo-siliceous concretions. But we think the preponderance of chalcedony and the general similarity of the nodules to those of chert in other limestones entitle them to come under that designation.

We have also examined the two conspicuously hard beds which occur in the chalk above the horizon of the chert-like nodules. Neither of them contains any colloid silica, but many of the coarser shelly fragments they contain appear to have been replaced by chalcedonic or crystalline silica. The silicified prisms of *Inoceramus*-shell are common in the uppermost bed, which is probably a continuation of that about the same horizon at Allington.

Chemical Composition of the Siliceous Beds.

Microscopical examination having revealed the presence of a large amount of siliceous matter in some of our specimens, we were desirous of ascertaining the precise amount of this, and at the same time of determining the relative proportions of the amorphous or colloid silica in the beds where that seemed to be most abundant.

We had made a rough estimate of the proportionate amounts of the principal ingredients of the highest siliceous beds near Chilton by estimating the bulk of each visible in thin slices under the microscope, with the following results :—

Amorphous organic silica	about	20	per cent.
Inorganic silica and glauconite	,,	15	,,
Calcareous matter	,,	65	,,

This, however, could only give a general idea of the proportions, and we therefore had some analyses made for the purpose of obtaining more accurate results. The following analysis of the highest bed in the Chilton cutting was made for us by Mr. J. West Knights, the borough analyst for Cambridgeshire :—

Siliceous matter insoluble in hydrochloric acid.	33·6
Silica soluble in hydrochloric acid	·4
Oxide of iron and alumina	·8
Carbonate of lime	63·4
Carbonate of magnesia	1·5
Trace of alkalies and loss..................	·3
	100·0

Of the 33·6 per cent. of silica insoluble in hydrochloric acid, 15 per cent. was dissolved by a boiling solution of sodium carbonate. This analysis serves to give an idea of the general composition of the rock. The material was dried at a temperature high enough to dissipate all water; hence the absence of water in the analysis.

[Since this paper was written, one of us has had the opportunity of conferring with Mr. J. B. Harrison, formerly of Christ's College, Cambridge, and now Island Professor of Chemistry in Barbadoes. He kindly offered to separate the several kinds of siliceous matter for us by elutriation and solution in caustic potash, and a sample of the same bed was analyzed by him with the following results:—

Moisture	1·08
Combined water and traces of organic matter	3·18
Colloid silica	19·08
Quartz and a little mica	11·23
Clay and glauconite	·47
Carbonate of lime and magnesia by difference	64·96
	100·00

Prof. Harrison, therefore, makes the proportion of soluble silica rather higher, amounting to about 19 per cent. as compared with the 15·4 per cent. of the first analysis. It is possible, and even probable, that the proportion of organic silica varies considerably in different parts of the rock, and that to obtain an accurate estimate of the average amount, several samples should be pounded up and a small quantity of the powder so obtained submitted to analysis.

The method employed by Prof. Harrison in estimating the amounts of the several siliceous matters was as follows:—The sample was ground fine, and two portions of about 2 or 3 grams each were taken and dissolved in dilute acetic acid. One of these was evaporated to dryness, washed, and the residue weighed, which consists of the total iron, alumina, clay, silica, &c.; call this residue A: after ignition it is heated with concentrated sulphuric acid until decomposed, the residue boiled with dilute hydrochloric acid to remove iron and alumina, then with a mixture of caustic soda and carbonate of soda solution, which dissolves all amorphous silica and leaves the residue of mica and quartz-sand. The other portion is *not* evaporated, but washed free from lime-salts and then washed by suction with a hot solution of mixed caustic soda and carbonate of soda, washed until free from alkali, and weighed; this (B) gives the clay, glauconite, and insoluble silica. The difference between A and B gives the soluble silica.]

It only remained to test the Eastcott chalk in which the peculiar cherty nodules were found and to see if that material gave similar results. A sample of this was sent to Mr. J. Brierley, the Borough Analyst of Southampton, who had very kindly offered to estimate the proportion of soluble silica for us; and we quote the following from his report:—

"The total insoluble matter, after evaporating the hydrochloric-acid solution, was 35·17 per cent.; of this there was

"Soluble in alkaline carbonate after boiling 15 minutes	12·61
Insoluble in the same	22·56
	35·17

"The silica formed such a network that it prevented the acid getting at the carbonate of lime to dissolve it, the effervescence ceasing till a portion was broken off and a fresh surface exposed. The mass had to be rubbed down with a pestle to make sure of the acid dissolving out all soluble matter and thoroughly decomposing all soluble silicates [if any existed]. I preferred to do this rather than powder the chalk previously, as it afforded a better idea of the distribution of the silica and the constitution of the sample."

The only question which remains is whether any silicates exist in the specimen which would be decomposed by the action of the hydrochloric acid and leave their silica free to swell the amount subsequently dissolved in the alkaline carbonate. The only silicate present in appreciable quantity is glauconite, and, so far as we can ascertain, this is not acted on by the acid at ordinary temperatures; for the grains and rod-like fragments of this mineral appeared to be unaltered when examined under the microscope after the chalk was treated with cold acid and the residue boiled for 20 minutes in caustic potash. Hot acid, however, decomposes glauconite with separation of silica, and the amounts of soluble silica in Mr. Knights' and Mr. Brierley's analyses may include such separated silica. Prof. Harrison used a special method of estimation, which avoids this difficulty and gives a more accurate result (see p. 414).

Résumé and Conclusions.

We have shown that in the Lower Chalk of Berkshire and Wiltshire there are beds which contain a large amount of disseminated colloid silica, and are comparable in general structure to the Malmstones of the Upper Greensand. Dr. Hinde's study of the latter led him to believe that the globular colloid silica which they contain has been directly derived from the remains of siliceous sponges, and the study of our Chalk specimens has confirmed his conclusion by adding several important pieces of evidence. Thus the contrast between the specimens which contain disseminated colloid silica, and that which contains none but in which the sponge-spicules are mostly, if not all, siliceous, is highly suggestive of the inference that the disseminated silica was largely, if not wholly, derived from the spicules. Again, we find that the amount of free disseminated silica increases in proportion to the number of spicules, and calcite casts of spicules, which occur in the rock. The great similarity between the siliceous chalk and the Malmstone is also heightened by the occurrence of similar siliceous concretions in both rocks, the material of which may be described as siliceous chalk indurated by a cement of chalcedonic silica.

Let us now recapitulate the several conditions in which the silica occurs in the Lower Chalk, stating them in an order which proceeds from the least to the most siliceous kind of rock:—

1. There is a chalk which differs from ordinary Chalk Marl only in containing numerous sponge-spicules, and these are all, or nearly all, of silica, which is but slightly changed from the clear colloid condition in which it originally existed.

2. There is chalk in which a certain amount of free colloid silica occurs, but it is disseminated through the mass in the form of very minute globules, so small that they can hardly be recognized with a power of less than an eighth of an inch (=640 diams.). This silica is generally associated with very small sponge-spicules.

3. There is chalk which contains aggregations of larger globules of silica, easily distinguishable with a quarter-inch objective (*i. e.* 200 diams.), and this chalk always contains a larger number of spicules, many of them being of large size. Such chalk does not fall to powder when placed in acid, but the insoluble residue stands as a firm siliceous mass.

4. There is a chert-like nodule which differs from the last only in being permeated and indurated by an infiltration of chalcedonic silica, this having replaced some, but not all, of the calcareous matter.

Leaving the chalcedonic silica out of consideration for the moment, we have in the most siliceous chalk an amount of colloid silica estimated at from 15 to 19 per cent. by weight, and possibly more in volume. Again the matrix of some portions of the Surrey Malmstone is almost entirely made up of such silica, and the total amount of so-called soluble (or colloid) silica present in such samples was estimated by Messrs. Paine and Way at from 50 to 75 per cent. Now, as the mass of siliceous chalk at Eastcott is at least 10 feet thick, as the Surrey Malmstone is estimated at 25 feet, and that of Oxfordshire and Berkshire attains a maximum thickness of 70 or 80 feet, the amount of disseminated colloid silica in these rocks is obviously very large.

If, therefore, we are to assume that all this silica has in some way or other been furnished by the spicules of siliceous sponges, we may feel a difficulty in understanding how there came to be such an accumulation of spicules as would be required for the supply of this silica. Without the knowledge of some recently published facts, it would undoubtedly have been difficult to account satisfactorily for the existence of so many separate spicules. We might certainly have supposed that many hundred thousand siliceous sponges have lived and died on the sea-floors represented by these beds, and that they were of species whose skeletons were entirely composed of spicules; this, indeed, Dr. Hinde informs us, was the case with the sponges to which the spicules occurring in the Malmstones belong. We might, too, have supplemented this source of supply by supposing that many were drifted from distant colonies of sponges, borne by the same currents that carried the fine inorganic particles which occur in the matrix. These, however, were

probably surface-currents, which gradually lost their force, and allowed their burden to subside, whereas the spicules would have to be picked up from the sea-floor and carried onward.

The action of gentle bottom-currents may perhaps partly account for the wide distribution of the spicules; but Prof. W. J. Sollas has furnished us with a sufficient reason for their wide-spread abundance. He has found that many, if not all, siliceous sponges are continually shedding some of their spicules, and that the number of spicules shed by such a sponge during its lifetime must be very great, and may possibly be larger than the number of spicules existing at any one time in the sponge itself. The facts will be found in his Report on the siliceous sponges collected by the 'Challenger' Expedition, but we quote the following from another publication:—"In one case (*Cydonium neptuni*) they [the shed spicules] accumulate within certain cavities of the interior of the sponge, completely filling them up, so that they look as if stuffed with cotton-wool: the quantity of spicules so preserved must, I should imagine, amount to at least one-fifth of the total quantity present in the sponge; but these are only what, by an accident of structural character, are preserved and can be seen. How many others have been extruded at the surface, fallen on the sea-floor, and left no trace of their previous connexion with the sponge behind, we do not know, and have no means of knowing. But it is a very suggestive fact that at one of the stations from which the 'Challenger' obtained sponges in great numbers (Station 149, off Kerguelen), the mud of the sea-floor from which the sponges were dredged is crammed full of sponge-spicules; and though the majority of these may have been derived from dead sponges, yet a goodly proportion may quite fairly be regarded as having been cast out from the living sponges"*.

These facts enable us to understand the abundance and the wide distribution of the spicules which seem to have supplied the material for the formation of the disseminated globular silica.

The next point for consideration is whether the formation and accumulation of the globular silica went on contemporaneously with the deposition of the calcareous material on the sea-floor, or whether the conversion of the spicules into such silica took place after the consolidation of the rock. Dr. Hinde believes that, in the case of the Malmstones †, the deposition of the silica took place after the consolidation of the rock; he supposes the silica to have been derived from the spicules, of which some of the empty casts can be seen, and that the material of these was dissolved by water percolating through the rock, and redeposited in the form of globular colloid silica. We find, however, much difficulty in accepting this view of the formation of Malmstone, and much more difficulty in applying it to the case of the siliceous chalk.

When we consider the occurrence of colloid silica in a similar globular condition diffused throughout the calcareous material of a

* "A Contribution to the History of Flints," Proc. Roy. Dubl. Soc. vol. vi. pt. 1 (1887).

† Phil. Trans. 1885, part ii. p. 403.

bed of chalk, the re-arrangement of particles throughout the whole mass of the rock can hardly be imagined as having taken place after even partial consolidation. In the case of a calcareous ooze containing numerous spicules, and partially consolidated, *i. e.*, compacted and compressed by the weight of overlying deposits, the spicules might be dissolved, but the silica could hardly be re-deposited within the same bed without a replacement of some part of the material forming that bed.

It seems to us that the most natural conclusion to be drawn from the facts is that the intimate mixture of calcareous and siliceous material was formed before the consolidation of the rock, and while it was still in a sufficiently oozy condition to admit of easy molecular redistribution; and we think that this was the case with the Malmstone as well.

We are, of course, prepared to admit that the empty casts of spicules which occur in the Malmstones, and occasionally in the Chalk, prove that some spicules were dissolved after the consolidation of the rocks; but we see no reason to think that the silica from these particular spicules has gone to form any part of the globular silica which is disseminated through the rock, and makes up so large a part of their mass.

The final problem presented for our consideration is to ascertain the manner in which the globular silica was formed and disseminated through the beds of chalk. This is a question in chemical geology, for the proper discussion of which we do not feel ourselves very well fitted, and the remarks we venture to offer must be taken as suggestive, rather than as the expressions of qualified opinion.

We were at first inclined to think that the disseminated colloid silica had been derived directly from the disintegration of spicules in which the globular structure had been previously developed; this molecular change in the substance of the spicules may, in fact, be seen in every stage of progress, and we thought it possible that when the globules had been so formed they might resist the action of solvents better than the unaltered outer wall of the spicule, so that when set free by the solution of the latter they would become mixed with and distributed through the surrounding calcareous ooze.

This theory would satisfactorily explain the existence of the disseminated silica in a globular form without the necessity of supposing that it had gone through a process of solution and precipitation as colloïd silica, but it did not prove to be in accordance with all the observed facts. If the silica only occurred in the shape of free globules or in linear series of globules, there would be less difficulty; but it often occurs in irregular masses or lumps far larger than the diameter of any spicule, and in such lumps it is only on the outside that well-formed globules can be seen, the inside showing only an indefinite kind of segregation, as if the mass had grown too rapidly for the development of free circular surfaces. The existence of such bunches or aggregations of malformed globules seems, indeed, to indicate growth or precipitation from solution.

Again, colloid silica of the same character often fills the chambers of Foraminifera, and in other cases half-globules or discs of such silica are seen clinging to both the inner and outer surfaces of a Foraminiferal chamber—modes of occurrence which it is difficult, if not impossible, to account for on any theory except that of precipitation from solution.

We are therefore compelled to suppose that the globular silica was precipitated from solution, and that this precipitation took place before the consolidation of the beds, and while they were still permeated by sea-water. That oceanic waters contain silica in solution is certain, because it must be from such a solution of silica that the sponges obtain the material secreted in their spicular skeletons, and in deep water, where the pressure is great, the amount of silica in solution may be considerable; but it is very difficult to understand the precipitation of any of this dissolved silica without the intervention of organic agencies. It is hardly possible to conceive conditions under which the water could contain a saturated solution of silica; but we may perhaps imagine that the water which lies over large fields of sponge-spicules holds more silica in solution than that overlying more calcareous bottoms, which may perhaps be saturated with carbonate of lime. If this were so, and if a gentle current then brought the lime-bearing water into the siliceous tract, it is perhaps conceivable that some of the silica might be displaced by the lime; but we admit that we are here losing ourselves in the realms of speculation.

In the above considerations we have already dealt only with the colloid silica, because it seemed clear to us that the precipitation of the chalcedonic silica of the cherty nodules was a secondary and subsequent operation, and that the conditions under which it took place were different from those which favoured the precipitation of the colloid globular silica. We are disposed to regard all nodular concretions resembling flints and phosphatic nodules as growths which were more or less contemporaneous with the deposition of the materials of the enclosing rock; and we should not accept the view that the cherty nodules in the Malmstone and Lower Chalk were formed after the consolidation of those rocks without very strong evidence to that effect. We are, however, inclined to connect the disappearance of the silica which once occupied the empty spicule-casts, and that of the spicules which are now replaced by calcite, with the formation of the chalcedonic nodules; and if this is correct, the rocks must have been so far consolidated that little mechanical movement of their component particles could be effected. If, however, masses of colloid protoplasm like those described by Dr. Wallich * were enclosed in the deposit, their slow and gradual decomposition might conceivably set up chemical reactions, whereby the silica of the spicules in the surrounding mass might be dissolved and re-deposited in the place of the organic matter.

We are here approaching the problem of the formation of flints, and we think it will hardly be denied that the existence of the four kinds

* Quart. Journ. Geol. Soc. vol. xxxvi. p. 79.

of siliceous chalk mentioned on pp. 415–416 is suggestive of the inference that the first three are stages in the production of highly siliceous chalk, and that the fourth process has resulted in the formation of a nodule which bears a very strong resemblance to a flint. In this connexion we may refer to a paper by Prof. W. J. Sollas, written in 1880, wherein he states his belief that flints have been formed by the gradual elimination of the calcareous matter from a mass of siliceous chalk, and its replacement by silica. "Briefly to sum up," he says *, "a deposit of sponge-spicules accumulated in the chalk ooze, and in the presence of sea-water under pressure, entered into solution. Replacement of the calcareous material of the ooze then ensued, small shells, and many large ones too, being converted into silex; and siliceous chalk, not flint, was the result. The chambers of the Foraminifera and the interstices of the chalk were now filled up by a simple deposition of silica, and the siliceous chalk became converted into black flint, an incompletely silicified layer of chalk remaining as the white layer of its surface."

This theory was suggested by the presence of siliceous chalk, a mixture of chalky powder and siliceous spicules, inside certain flint nodules, and he was therefore imagining a different kind of siliceous chalk from that described in the preceding pages. The chert nodules, however, may be regarded as siliceous chalk (*i. e.* a mixture of chalk and colloid silica) still further silicified in the manner suggested by Prof. Sollas, but not so completely silicified as to be converted into flint. It is not difficult to imagine the effect of a further influx of silica in sufficient quantity to replace all the remaining calcareous matter; all the separate particles which are now distinguishable would then be obscured and merged into the solid translucent chalcedonic matrix or medium, just as the spicules which can sometimes be seen in hollow flints, half freely projecting, and half completely merged in the solid flint. Probably if these nodules had been converted into flints their colour would have been grey like those in the Middle Chalk of Lincolnshire.

Discussion.

Dr. Evans was struck with the difficulty which had been experienced in determining what was colloid silica. The term was liable to mislead. Flint had been defined as being of two kinds, a crystalline and an amorphous silica. The solubility materially varied with the solvent used. The ordinary chalk-flints contain much silica soluble in ordinary water; this is strictly colloid silica, and it has been removed from flint implements within human times. The question before the Society would be simplified if the real nature of colloid silica were better defined.

Dr. Hinde stated that the specimens and sections from the Chalk Marl exhibited by the Authors were of a precisely similar character to those which he had described from the Malmstones of the Upper Greensand. His own work was directed not so much to ascertain the

* Ann. & Mag. Nat. Hist. ser. 5, vol. vi. p. 449.

method by which the silica had reached its present condition as to show that it had been derived from sponge-remains, and this view was fully borne out by the Authors. He had depended to a great extent on optical evidence as to the presence of amorphous silica. The sections in which the silica was negative in polarized light between crossed nicols he had regarded as amorphous. The view that the accumulation of spicules in these fossil sponge-beds was mainly owing to the shedding of the spicules by the living sponges required confirmation; he believed it was rather due to the disintegrated skeletons of successive generations of these organisms.

Prof. SEELEY had doubts about the formation of colloid silica at the period of deposition of the roek. He believed the sponges furnished soluble matter to water percolating through the rock, and that the process had been going on for long ages.

Dr. HICKS differed from the last speaker as to his way of accounting for the silica found among the older rocks. The siliceous bands in the Carboniferous Limestone, for instance, must be considered contemporaneous deposits.

Mr. HILL could not define at present what was or was not colloid silica. In answer to Prof. Seeley, he observed that there were in the Chalk-Marl of Wiltshire beds containing quantities of shell-fragments the material of which was replaced by silica; he thought if silica was deposited by percolating water, as Prof. Seeley suggested, it would hardly be in the globular form.

28. *The* Northern Slopes *of* Cader Idris. By Grenville A. J. Cole, Esq., F.G.S., *and* A. Vaughan Jennings, Esq., F.L.S. (Read April 17, 1889.)

I. *The General Features of the Surface* (Fig. 1).

Since the year 1829, when Mr. Aikin published in the Transactions of the Geological Society of London his "Notes on the Geological Structure of Cader Idris" *, much attention has been called to the stratigraphy of the district, while the maps and memoir of the Government Survey have guided numerous workers and have pointed out the relics of eruptive activity in which Merionethshire abounds.

Mr. Aikin, while describing the general features presented by the rock-masses as they succeed one another on the mountain-side, notes also many of their mineral peculiarities, combining in his paper the breadth of view and accuracy of detail that characterize so markedly the works of many early observers, pioneers whose knowledge was largely dependent upon personal researches in the field.

Sir A. C. Ramsay, in the first and second editions of his "Geology of North Wales" †, deals fully with the physical structure and relations of the slate-beds, the ashes, and the intrusive sheets that rise tier upon tier above Dolgelley. We have thought, however, that some further investigation into the nature of the eruptions in this area, and the characters of their products at successive stratigraphical horizons, might even now add somewhat to the interest with which all geologists, in common with all lovers of scenery, regard the heights of Cader Idris. The publication of the six-inch Ordnance map, though too late to be of service in our earlier observations, has enabled us to ascertain the height of many points with precision, and to better estimate the thickness of the various groups of rocks ‡.

Despite the fine valley descending to Tal-y-llyn, and the cliffs of Cwm-ammarch and Pen-coed, the northern slopes of the mountain are by far the most attractive from a structural and geological point of view. The strata and their intercalated igneous material dip to the south and to the south-east, forming one flank of Sedgwick's "Merionethshire anticlinal;" and their denuded edges form a series of bold escarpments that face the Harlech plateaux on the north. Aided by these exposures, Prof. Sedgwick, in a memorable paper in 1847 §, traced the succession of "fossiliferous slates" and "con-

* Trans. Geol. Soc. ser. 2, vol. ii. p. 273.

† Memoirs of Geol. Survey of Gt. Britain, vol. iii. 2nd edition, 1881.

‡ We have followed this map in the spelling of names, in the hope of securing uniformity.

§ "On the Classification of the Fossiliferous Slates of North Wales, Cumberland, Westmoreland, and Lancashire," Quart. Journ. Geol. Soc. vol. iii. pp. 133-164.

temporaneous porphyries" from the Barmouth estuary across Cader Idris to Machynlleth, recognizing his Ffestiniog and Tremadoc group in the foot-hills near Arthog and Dolgelley.

Above these picturesque and wooded promontories, some six or seven hundred feet in height, the ground rises for another eleven hundred feet as a broken grassy upland, set with little scattered cliffs, the slopes being easy of ascent except to the west of Tyrau Mawr, where the valley between the lower and upper ranges is rapidly narrowing to its head. On the east, the glaciated front of Mynydd-y-Gader, the "Stony Mountain" of Mr. Aikin, forms a bold contrast to these green and softer ledges.

From this level the great wall of Cader Idris rises, with several picturesque lakelets at its foot, a precipice some seven miles long and at its boldest point nine hundred feet in height. Across it, however, there are several easy foot-tracks, and from its crest the dip-slope of the hills can be seen descending southward, smooth and grass-covered, to the Towyn valley and Tal-y-llyn.

II. *The Tuffs and Sedimentary Deposits.*

Starting southward from the level of Llyn Gwernen, on the old Dolgelley and Towyn road, the first rocks encountered on these northern slopes are the black slates so well displayed in the deep pit-like quarry of Penrhyn-gwyn. The cleavage is almost perpendicular to the bedding, which dips here somewhat west of south. On the uppermost ledge of the excavation the first evidence of contemporaneous volcanic activity occurs. A grey amygdaloidal andesite, five to six feet thick, rests upon the cleavage-edges of the slates, being itself only slightly affected by the earth-pressures of the district.

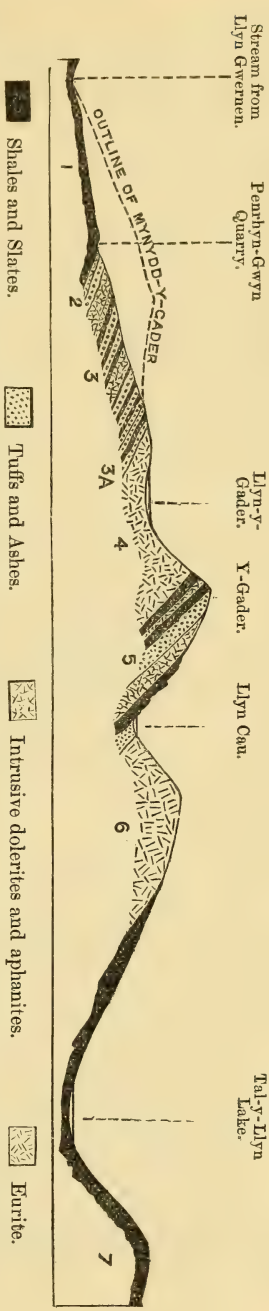


Fig. 1.—*Lithological Section through Cader Idris.* (Scale, vertical and horizontal, $1\frac{1}{2}$ inch = 1 mile.)

The calcite, however, that fills up the vesicles of this rock has become bent and even granulated, as may be seen in microscopic sections; the porphyritic felspars, which are plagioclastic, are also largely replaced by calcite, and lie in a fine-grained matrix of prismatic plagioclase-felspar and granular altered pyroxene. The beds immediately below have been converted into spotted slate, and the igneous mass appears to be an intrusive sheet rather than an actual lava-flow.

However this may be, it is followed by a considerable thickness of grey volcanic tuff, in marked contrast to the compact dark slates below; felspar crystals, about one eighth of a inch in length, are freely scattered through this deposit, accompanied by slaty fragments, the abundance of which points to considerable volcanic activity. The flakes and lenticular fragments of clay and shale thus torn from the old sea-floor appear to have shrunk and cracked internally during the consolidation of the tuff. On exposure, a septarian structure is often revealed towards the centre, which becomes brown on weathering, while the outer portion, and the entire flake in smaller instances, has become dense and irregularly fissile, exhibiting a lustrous surface like that of slickensided slate. These argillaceous fragments, sometimes six or seven inches long, flung out imperfectly consolidated among the first products of eruption, may have been baked and metamorphosed, externally at any rate, by the invading igneous sheets, and have subsequently acquired some of the characters of slate. The larger fragments appear as elongated and flattened "eyes" in the midst of the more yielding ash; while the smaller pellets, on the other hand, spread out by dynamic action, have given rise to the thin black lustrous films that occur so frequently in this rock.

Under the microscope the tuff is seen to abound in particles of scoriaceous andesite-glass, now converted into a green palagonite; and round these, as well as round the scattered plagioclastic felspars, the fine interstitial ash has assumed a kind of flow. Flecks of iron pyrites are very common.

Similar tuffs with black clayey inclusions are well seen at the base of the Snowdonian eruptive series, as at Llyn Llydau and between Rhyddu and Beddgelert. Comparison is naturally suggested with the well-known beds in the Vorder Eifel, where, however, a still greater contrast is afforded by the hard cleaved particles of Devonian slate and the loose ash in which they lie.

The upper portion of this slate-tuff, or shale-tuff at the time of its formation, passes into a compacter ash, above which dolerite occurs. The higher slopes, rising another thousand feet as far as the floor of Llyn-y-Gader, consist of repetitions of slate-tuff and abundant finely bedded ash, in which intrusive sheets, of fairly basic character and of very various grain, have produced extensive alteration.

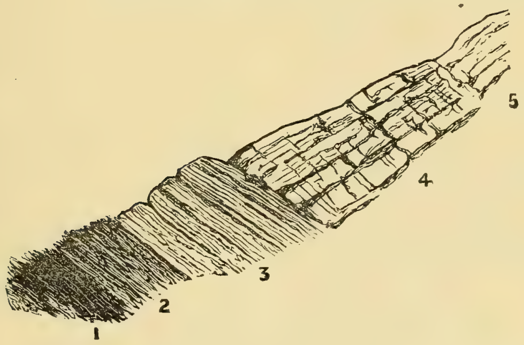
Below the north-east face of Tyrau Mawr, and among the earlier layers, one of the coarser tuffs contains bomb-like masses six inches

or more across. In their cracked and scoriaceous interior calcite has developed freely, so much so as to suggest at first the presence of ejected limestone blocks. After boiling this crystalline alteration-product in hydrochloric acid, the residue yields little of interest, quartz and a few brown flakes of mica being the only identifiable minerals.

Prof. Ramsay * has commented on the difficulty of distinguishing between the compacter intrusive sheets, themselves often scoriaceous, and the soft grey-green ash-beds. On the broken slopes between Llyn-y-Gafr and Llyn-y-Gader the cleavage of the district has affected some of the igneous layers, while every crack and hollow is filled with secondary calcite. Hence the rocks afford, when considered in the laboratory, excellent hand-specimens of "Schalstein;" but to designate them by such a name is to admit that we are baffled in the field.

Some of the undoubted ash-beds, even when soft and calcareous, are divided by jointing into spike-like columns; while the compacter and more metamorphosed ashes at the base of the cliff of Mynydd

Fig. 2.—*Beds beneath the Eurite on Mynydd Moel.*



1. Black Slates, with cleavage practically coincident with bedding.
2. Altered flinty slates, with well-marked bedding.
3. Greenish softer layer.
4. Bedded Ash, altered and jointed into columns.
5. The Massive Eurite.

Moel imitate closely the columnar eurite of the wall (fig. 2). The fine layers of the bedding, however, frequently weather out, and give a clue to the origin of the rock; while microscopic examination removes many of the difficulties presented by the porcellaneous varieties †.

* Memoirs of the Geol. Surv. of Gt. Britain, vol. iii. 2nd edition, p. 31.

† Mr. J. Clifton Ward discussed the microscopic characters of somewhat similar ashes in his paper on the "Structure of Ancient and Modern Volcanic Rocks," Quart. Journ. Geol. Soc. vol. xxxi. (1875) p. 403.

In places, as on the ridge of Mynydd-y-Gader, where the alteration due to the dolerites is displayed with admirable clearness, the ejected blocks standing out from their hornstone matrix sufficiently indicate the original character of the rock.

Again and again the black slates assert themselves, the muddy sediments of more quiet waters, to be covered in their turn by the products of explosive action. The "pisolitic ironstone" of the Llyn-Aran area occurs as a hard black band among the higher of these normal sediments. A handsome specimen of the rock, kindly sent us by Mr. Jones of Gwernan Villa, shows numerous clayey concretions an inch or so in length, and contains a large quantity of disseminated pyrrhotite. This magnetic pyrites itself forms in places concentrically-built ovoid concretions.

A microscopic section, cut from a specimen obtained by us nearer the Cross Foxes Inn, reveals the characteristic "pisolitic" structure in a very pleasing manner. But for traditional usage, the rock might be preferably termed "oolitic;" for the grains, distinctly seen on the surface, are barely a millimetre in diameter. With transmitted light they appear green, with a well-developed concentric structure. Here and there a shell-fragment or other foreign body is seen, round which the grain has formed. The bulk of the iron is now represented by little cubes of magnetite, which have separated out most extensively in the interstitial matter, but which also mark certain of the concentric coats of the grains. Minute nests of a fibrous green mineral also occur throughout the matrix.

The majority of the grains are ellipsoidal rather than spherical, and in such cases, on rotating the section between crossed nicols, the arms of the characteristic dark cross are seen to approach or to recede from one another. From this we conclude that the crystalline particles, whether original or pseudomorphic, have been added so that one direction of extinction lies tangentially, the other therefore, in the vast majority of cases, not pointing directly towards the centre of the ellipsoid *. In this respect the grains resemble those of the pisolite of Carlsbad and of oolitic limestones now in course of formation †; but we hesitate to express an opinion as to the chemical constitution of the green mineral of which they are now composed. The use of the quartz-wedge shows that the tangential direction is that of minimum elasticity; and the feeble pleochroism gives a bluish-green tint when this direction is parallel to the shorter diagonal of the nicol, and a pale yellow-green when rotated through 90°. If, moreover, a polished surface of the rock is etched with strong hydrochloric acid, the greatest solution occurs where the magnetite is developed, and the least where the green substance predominates. After boiling small fragments of the rock in hydro-

* Of course the particles that have been added along the axes of the elliptical section have one direction of elasticity pointing towards the centre; and it follows that when the axes of the section are placed parallel to the diagonals of the nicols the dark cross becomes normal and rectangular.

† See Sorby, Quart. Journ. Geol. Soc. vol. xxxv. (1879), Proc. p. 74.

chloric acid, a residue of dusky grey or colourless matter remains. In this some pumiceous particles may be made out; but the oolitic grains themselves leave a siliceous residue, which no longer affects polarized light, although the concentric structure is retained. It will be seen how the discussion of the Liassic ironstone of Cleveland by Mr. Sorby * and of the Northamptonshire ores by Prof. Judd † applies also to this older and more metamorphosed deposit.

In connexion with Prof. Judd's observations on the presence of phosphoric acid in the greener varieties of the Northampton ore ‡, we may remark that the ironstone of Cader Idris gives a distinct reaction when treated with a nitric-acid solution of ammonic molybdate.

Thus we are led to regard the oolitic structure in this ironstone as original. The carbonate of iron which, in all probability, replaced the calcite or aragonite of the grains has now itself been broken up, leaving the cubes of magnetite as a residue. The rock still effervesces slightly when boiled in hydrochloric acid; but the ease with which its powder is attracted by the magnet shows that the bulk of the iron is now in the oxidized condition. The alteration having taken place as a deep-seated process and not in contact with the air, neither hæmatite nor limonite has been developed. A specimen of the pisolitic ironstone of Pen-y-morfa near Tremadoc, for which we are indebted to Mr. G. J. Williams, F.G.S., is still more strikingly magnetic.

If the iron-ore of Cader Idris was at one time a fairly calcareous band among the more prevalent muds and shales, it owes its preservation to the pseudomorphic action that has gone on. The very marked proportion of carbonate of lime that occurs in the cavities of the permeable rocks from Llyn Gwernen to the summit of the mountain may have been in part derived from similar seams or shelly patches, the absence of which we have so frequently to deplore when examining Ordovician or Cambrian strata. It is unnecessary to dwell upon the increased effect of solvent action when occurring in a region subjected to pressure and earth-movement.

On the east flank of Tyrau Mawr, and above the mass of the main eurite, volcanic beds with slaty fragments recur at a height of eighteen hundred feet (fig. 3). At this point the junction of the tuff with the overlying normal slate is marked by a thin white band consisting of granules of quartz and decomposed felspar; it would seem that this sand is a washed residue from the uppermost layers of the tuff, such as would be formed by the action of waves or currents prior to the next sedimentation.

Close to the foot of the Roman road, where it descends in bold zigzags from Craig Glâs, the talus is strewn with blocks of coarse felspathic tuff, which include wisps of shale more conspicuous than those of Penrhyn-gwyn. The dimensions of the surface here figured

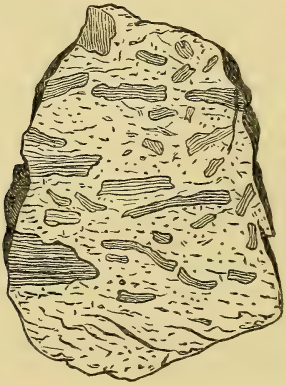
* Quart. Journ. Geol. Soc. vol. xxxv. (1879), Proc. p. 84.
† Mem. Geol. Survey, "Geology of Rutland," pp. 117–138.
‡ *Loc. cit.* p. 127.

(fig. 4) will convey some idea of the characters of this deposit. The compact grey matrix of the tuff, with its abundant felspars, makes it resemble to the eye an intrusive felstone with inclusions.

The larger fragments of lava thrown into these tuffs serve, far better than the easily altered and more permeable matrix, to record the nature of the rocks that were formed at the centre of eruption.

Fig. 3.—*Tuff with Felspar-crystals and fragments of Slate and Vesicular Glass. East flank of Tyrau Mawr.* (× 8.)

Fig. 4.—*Joint-surface of block of Tuff, showing included Slate-fragments. North slope of Tyrau Mawr.* (Size 7 feet by 4 feet 6 inches.)



The absence of lava-flows in this locality leads one to depend upon less satisfactory evidence; but there is here no reason to suppose that the abundant scoriaceous or compacter masses in the tuffs were torn from some more ancient and deep-seated deposits.

Microscopic examination shows that the tuffs with felspar crystals and slaty fragments preserve, throughout some 2500 feet of sediments and intercalated sheets, characters closely similar to those of the bed at Penrhyn-gwyn. In specimens collected at the higher levels, the proportion of palagonitic scoriæ is diminished; and on the west flank of Tyrau Mawr grains of quartz containing liquid-inclusions appear among the ejected materials. Here also, shortly above the massive eurite, is a bed containing white and very irregular fragments, some of them an inch or two across. The forms of these, under the microscope, strongly suggest those of shattered scoriaceous glass; and the resistance they have offered to decomposition, and the extreme sharpness of their outlines, would ally them to the trachytes or even to the rhyolites. They exhibit traces of brown spherulitic and "microfelsitic" structures, which are now mere dendritic patches through the development around them and in them of the transparent products of secondary devitrification. A few porphyritic felspars occur in the larger fragments of the glass, and minute chalcedonic spherules, giving a black cross and vivid colours between crossed nicols, are in places developed very freely. We find here, then, a deposit that links the normal slaty tuffs with the undoubtedly acid products of the latest phases of eruption.

Some 1100 feet lower in the series, omitting the thickness of the intrusive eurite, the metamorphosed porcellaneous tuffs on Mynydd-y-Gader contain blocks that weather white on the outside, and exhibit within the compact blue-grey appearance of the altered rhyolites of Wales. While many of these were undoubtedly scoriæ, others prove to be, as Prof. Ramsay stated, concretions developed in the tuff, or at any rate, as the microscope would indicate, ejected lumps from previously consolidated tuffs. One of these "concretions," five inches in length, has a specific gravity of 2·62. Wisps of colourless devitrified glass and larger fragments of pumice form the ground-mass of this specimen, while the adjacent tuff contains more slaty matter and palagonite.

A true ejected scoria from the south-west corner of Mynydd-y-Gader contains corroded grains of quartz, exhibits traces of fluidal structure, and would rank, could it be restored to its original condition, with the quartz-andesites or the rhyolites. The nature of the porphyritic felspars has been masked, in this case, by kaolinization.

Another and greyer lump from close below Llyn-y-Gafr is, allowing for devitrification, a good porphyritic trachyte, all the more typical for containing some plagioclastic as well as orthoclastic felspar. The cracks in the compact matrix of this rock have a rude perlitic tendency.

In one at least of the ash-beds on Mynydd-y-Gader numerous quartz-grains occur, often rounded and containing intruded material; these have been derived, it would appear, from some fairly acid and vitreous lava. Felspar crystals are comparatively rare in this deposit,

which was probably mainly composed of comminuted glassy particles, and yielded easily to metamorphic agents during the intrusion of the dolerite below.

As might be expected, this fine-grained ash has not undergone actual fusion, although it has been converted into a hornstone or porcellanite, in which the original nature of the constituents is no longer determinable even under the higher powers of the microscope. The imbedded quartz-grains have since become enlarged, the added silica being, as usual, in optical continuity with that of the original grain, and in some cases spreading outward in short processes into the microgranular material around. The specific gravity of a compact specimen of this altered rock is 2·64.

These examples will suffice to show that the great series of tuffs and ashes contains beds of fairly acid characters, particularly as the higher members are approached, though some reversions occasionally occur towards the andesitic type of Penrhyn-gwyn. We confess, however, that we were unprepared to find among the still later beds of the Tal-y-llyn valley such perfect examples of devitrified glassy lavas as occur upon the cliffs of Craig-y-Llam. The igneous rocks are here mapped as "interbedded felspathic trap," but include much flinty felsitic ash, the fine stratification of which resembles, in hand-specimens, the fluidal structure of a rhyolite. Some of the imbedded fragments show under the microscope a perlitic structure of the most

Fig. 5.—*Compressed Tuff, containing fragments of Vesicular and Perlitic Lavas, and showing round many of these a zone of crushed and drawn-out material. Craig-y-Llam.* (× 8.)

complete and delicate kind, the cracks being occupied by a green pleochroic alteration-product (fig. 5). Others exhibit remains of spherulites in a similarly perlitic matrix. A specimen of the lavas of this horizon contains altered spherulites measuring half an inch across, the fluidal structure passing through them; they are partly decomposed and hollowed, with infillings of granular quartz. The surrounding perlitic matrix has been much deformed by pressure, and lines of

liquid-inclusions have developed in the secondary quartz, passing from grain to grain as in the spherulitic rock of Digoed *. The lavas of Craig-y-Llam thus parallel, even in minor details, the well-known "felsites" of the Snowdon area, which are indisputably of Bala age.

Similar rocks form a great part of the opposing slopes rising above Minffordd to Llyn-y-Cau.

III. *The Dolerites and allied Intrusive Sheets.*

While much of the massive "greenstone" apparent on the published maps can be resolved into tuffs and sedimentary layers, there remain the more basic intrusive sheets, which have been already referred to and which are too numerous to be separately set down on the scale of one inch to the mile.

The frequent alternation of the ash-beds with normal marine deposits shows that the centres of eruption were at some distance from the present mountain; and the absence of lava-flows and coarse agglomerates points distinctly to the same conclusion. Hence true volcanic necks are unlikely to occur in the district dealt with in this paper, and an examination of the more suggestive and extensive areas marked as "greenstone" on the map reveals again and again the composite character of these masses. Thus the coarse dolerite of the quarry between Rhyd-wen and Bron-y-Gader, one mile south-west of Dolgelley, proves to be of small extent at the surface, and to be itself associated with bedded ash and porphyrites of finer grain.

The mass forming the high ridge of Mynydd-y-Gader is, however, more continuous, and is one of the most striking features of the mountain. The picturesque hollows of its summit, crossed by roaring streamlets, and its northern escarpment, steep and glaciated, exposed for some four hundred feet, afford one ample opportunities for observation, but force one to regard even this mass as a highly developed intrusive sheet. There is no indication here of the great central intrusions, the irregular ramifications, the plexus of dykes and veins, that characterize the cores of old volcanoes when at length exposed by denudation.

The broad "greenstone" band, three miles long, which appears upon all recent copies of the map at the base of the cliff of Cader Idris, has been already shown to consist of a considerable variety of rocks, ranging from slate to dolerite, the whole series having the east-and-west strike so persistent on these northern slopes. Prof. Ramsay himself, in the Survey memoir, calls attention to its complex character. The "tesselated" appearance of the sheets, where jointed into columns †, is frequently seen upon surfaces dipping at 35, 40, or even 50 degrees.

* Quart. Journ. Geol. Soc. vol. xlii. pl. ix. fig. 5.

† Mem. Geol. Survey of Great Britain, vol. iii. 2nd edit. p. 31.

It is obvious from the first examination in the field that these intrusive sheets, which one may comprehensively class as diabases *, have undergone considerable alteration. Calcite is very freely developed; while quartz-veins are conspicuous in the large quarry near Bron-y-Gader, where they were formed prior to the infiltration or formation of the carbonate of lime. In this quarry Mr. Aikin observed epidote, which he describes as "fibres and curved crystals of pale wine-yellow thallite." While small epidotes are certainly abundant, the larger acicular crystals collected by ourselves prove to be actinolite and tremolite; and we have noticed also greenish asbestos in the clefts on the northern face of Mynydd-y-Gader.

Under the microscope the original characters of these diabases can be determined with some accuracy, despite the wide development of secondary products. Thus the coarser varieties, like the rock of Bwlch-yr-hendref on the west and that of Bron-y-Gader on the east, were clearly dolerites approaching gabbro, with a well-developed ophitic structure. The mass at Bron-y-Gader contains stout porphyritic felspars and pale secondary hornblende. The rock rising like a weathered dyke on the south shore of the larger Crogenen Lake is particularly rich in plagioclastic felspar, both as porphyritic crystals and as a well-marked meshwork in the ground-mass; granular altered pyroxene occurs also interstitially, in the midst of what probably was once residual glass.

The handsome rock of the north front of Mynydd-y-Gader is, again, an ophitic dolerite of medium grain. The pale brown augite seems to have suffered little, and the included felspars are also fairly fresh. While the structure of some of these rocks points towards a basic composition, we have failed to detect pseudomorphs after olivine, and believe that the iron originally separated out was even smaller in amount than it appears at present.

The characteristic decomposition-product of these basic rocks is an epidote (colourless in thin sections) which occurs in every slide associated with chloritic areas. Its abundance, coupled with that of the all-pervading calcite, implies an immense withdrawal of lime from the original constituents. In fact, alumina and lime, rather than magnesia and iron, must have been the prevailing bases during these eruptions; and the same evidence is afforded by the very tough and compact "greenstones" either north or south of the old Towyn Road, which are merely fine-grained variations of the types already cited.

On the whole these diabases contain surprisingly little secondary quartz; but in one instance, that of a pale grey rock close under the cliff of Tyrau Mawr, this mineral occurs in the most striking manner, so that the mass at first suggests a porphyritic elvan. The microscope relegates this rock also to the andesites; but the general

* We use this term in the wide sense, and as an international equivalent of the loosely-applied English "greenstone."

structure and the imperfect development of the felspars indicate that it was more glassy than the other compact sheets of Cader Idris. The coarsely granular quartz, with inclusions of vermicular chlorite, fills cavities that may have been originally gas-vesicles. It is noteworthy that this development of quartz occurs, just as in the slates of the district, close to the contact with the massive and intrusive eurite.

These "greenstones" or "diabases" form, then, a series related rather to the augite-diorites and augite-andesites than to the normal gabbros and olivine-bearing basalts. They range from dolerites without olivine and aphanites to andesitic rocks with an originally glassy matrix.

On Rhobell-fawr, on the other hand, the imposing mass to the north of our area, we find examples of far more basic rocks, containing pophyritic altered olivine. We believe, moreover, that the beautiful "hornblende-diabase" of this mountain has no representative on Cader Idris.

In concluding this portion of our subject, we are not unmindful of the observations made by the late Mr. John Arthur Phillips on the alteration of uralite in a diabase from the Dolgelley area *.

IV. *The Massive Eurite* †.

Undoubtedly the most striking feature of Cader Idris is the precipitous escarpment of grey columnar rock that forms so large a portion of the mountain-wall. The main mass, running east and west, is faulted down at Tyrau Mawr, the bold cliff of which is

* Quart. Journ. Geol. Soc. vol. xxxiii. (1877), p. 427.

† We have adopted this name, after some deliberation, for a rock that might be classed in this country as a compact quartz-felsite. The term "felsite" is now so generally employed on the continent for that portion of a rock in which "felsitic" structure may be recognized, that its retention as a generic name has seemed to most geologists unadvisable. Klaproth's "felsit" appears to have been based on chemical characters, and Gerhard (Abhandl. der Berlin. Akad. der Wissensch. 1814 & 1815, p. 18), to whom the name is usually ascribed, while considering felsite as forming the ground-mass of various rocks, includes under it Werner's "Thonstein" and the Labradorite-rock of Labrador. He adduces, moreover, as allies, the pitchstone of Meissen and other substances, on the ground that they all consist of "Kiesel, Thonerde, Kalk, und Natrum." After this, it is idle to seek authority, other than Anglo-Saxon usage, for restricting "felsite" to any defined class of rocks.

Compare with this laxity of expression the definition of "eurite" by d'Aubuisson de Voisins (Traité de Géognosie, 1819, t. ii. p. 117):—"Dans le porphyre ordinaire, celui qui correspond au granite proprement dit, cette pâte aura le feldspath pour principe principal: nous lui donnons le nom d'eurite et nous la définissons en disant: *L'eurite est un granite compacte, ... d'apparence homogène, dans laquelle le feldspath est le principe dominant, et dont les divers principes sont comme fondus les uns dans les autres.* S'il était possible de la redissoudre, et de faire cristalliser tranquillement la solution, de manière à ce que les principes intégrants pussent se former en cristaux distincts, elle produirait un granite."

It is clear from what immediately follows in d'Aubuisson's treatise that the predominance of felspar is not strictly insisted on. On page 118 we read, "Si, dans le granite qui a produit l'eurite, ou qui est censé l'avoir produit, en devenant compacte, le feldspath était en très grande quantité, l'eurite se

composed of black slates and stratified ash. But along the face of Cyfrwy, around the gloomy pool of Llyn-y-Gader, and on the higher front of Mynydd Moel, this rock stretches with marked uniformity, dipping southward or south-westward with the strata, and strewing the taluses with angular fragments and columnar blocks that encroach upon the grass below. The weather has little effect on this detritus, beyond a slight browning of the surfaces, and the steeply piled grey accumulations are well contrasted with the soft terraces of the underlying tuffs.

The thickness of this principal mass is about 1500 feet; another sheet comes in below it on the level of the slates of Penrhyn-gwyn; and an additional mass, perhaps a faulted repetition of the second, is recognizable in the rounded hill-outlines and white exposures that extend from Llynau Crogenen to Gelli-lwyd-fawr. West of Tyrau Mawr, though at a lower level, the main mass forms the steep slopes near the road, and curves south, rising at the same time, till it resumes its place on the cliff above Llyn Cyri. The whole of the flat upland around this lake reveals the presence of the eurite, and between the white and angular fragments a bog has formed rather than a soil.

Everywhere its fractured surfaces present the same compact blue-grey appearance, faintly tinged with brown, the splintery fragments broken from it cutting like flakes of glass. The uniformity of its characters over separate exposures three and four miles in length would alone be strong evidence for regarding it as intrusive. The Survey map shows how it cuts on a large scale across the ashes and more basic sheets; and near the Roman road on Tyrau Mawr a short offshoot appears to us to run down into the ash and slates below. We are not at present prepared to discuss the continuity of the eurite from Craig-y-Llyn (Gallt-y-Llyn) across the southern slopes of the mountain to Llyn-y-Cau, since the rock on Llyn-y-Cau has more of the characters of a lava-flow, and part of the area mapped as "felspathic trap, intrusive" is occupied by highly silicated ashes and spherulitic rhyolites like those described on Craig-y-Llam. Curiously enough, further to the north-east, in a hollow under Gau Graig, the rock appears to have recovered its intrusive character, and abuts against altered slates in which quartz-veins are abundantly developed. It is at this point that a reddish rock with chloritic bands arises, simulating a gneiss when lying broken on the roads. Probably on

rapprochera beaucoup du feldspath compacte . . . mais si le quartz est abondant dans le granite, la roche . . . se rapprochera du quartz compacte (*hornstein*) ou kératite."

The "haelleflinta" of Sweden is appropriately introduced for comparison, and the connexion of the darker amphibolic eurites with aphanite is also pointed out. The specific gravity of eurite is stated to be 2·6 to 2·7 (Gerhard gives that of felsite as 2·980 to 3·020). The name is derived from the fusibility of the rock (? εὔροος).

Apart from the Neptunian views of d'Aubuisson, the lucidity and exactitude of these statements have impressed us in no slight degree. Unable to accept "quartz-porphyry," a term covering many ancient lavas as well as crystalline elvans, or "microgranulite," as used by several prominent French authors, it is with satisfaction that we fall back on "eurite" as a name for rocks intermediate between granite and the fresh or altered types of acid lavas.

this side of the mountain the eurite is near some line of emergence on the old sea-floor, a consideration that connects it in our minds with the Llandeilo lavas of Craig-y-Llam.

But on the northern slopes of Cader Idris the masses are, as already stated, very uniform in texture. On Mynydd Moel porphyritic felspars are more easily visible than at other places, but even here do not readily catch the eye *. The specific gravity of a blue-grey fresh-looking specimen from this point is 2·64. In section, the same specimen shows clear felspars, mainly plagioclastic, with wisp-like yellow and altered biotites and numerous grains of quartz; round these the matrix is exquisitely micropegmatitic. Small chloritic patches are frequent.

The typical rock at Llyn-y-Gader, where we have easy access to the centre of this huge intrusive sheet, shows the delicate micropegmatite collected into spherulitic forms around the quartz- and felspar-crystals. The little bunches and wisps of biotite occur independently of these aggregations. Though simply twinned felspars are here more common than at Mynydd Moel, the rock is still allied to the granitites or the soda-granites rather than to the normal granites. The interstices left between the well-developed spherulites are now mainly occupied by chlorite and a few highly refracting granules. It is unusual to find in a rock of this description so complete a separation between the micropegmatitic spherulites and the residual matrix round them.

A specimen collected from the mass to the south-west of Gelli-lwyd-fawr and north of the old Towyn road is of slightly coarser grain. The micropegmatite is far more distinct, and spherulitic grouping does not occur. Here and there the quartz has developed ophitically round felspars that lie at random with regard to one another. The rock is, however, essentially the same as the main eurite of the wall, and has a corresponding specific gravity of 2·63.

Through the kind permission of Prof. Judd we are able to give an analysis of the eurite of Cader Idris, which has been made by Mr. T. H. Holland, A.N.S.S., in the Geological Laboratory of the Normal School of Science and Royal School of Mines. The specimen used was taken from the columns on the south shore of Llyn-y-Gader.

Silica	72·79
Alumina	13·77
Ferric Oxide	3·32
Manganous Oxide	trace.
Lime	1·94
Magnesia	·62
Potash	2·99
Soda	4·12
Loss on Ignition	1·08
	100·63

* On the copies of the map that we have examined this promontory is coloured as interbedded trap, probably by an oversight, since it is clearly connected with the mass around Llyn-y-Gader.

It is interesting to possess this analysis of a rock with which almost every British geologist is familiar, and it confirms the relationship of this eurite to the granites rich in soda.

We believe that the mass must have been fairly, if minutely, crystalline at the time of its original consolidation; but it is obvious that any discussion of the "granophyric" structure of Rosenbusch must affect our views of this rock of Cader Idris, in company with a host of other British examples, closely agreeing with it in texture and in chemical composition.

V. *The Age and Duration of the Eruptions.*

Such being the relations and general characters of the rocks forming the northern slopes of Cader Idris, we have now to consider their position in the stratigraphical series.

It appears to be generally admitted that no indications of eruptive action occur in this district throughout the Lingula Flags; and volcanic activity is believed to have commenced in early Arenig times *. This view has been supported by the fact that on the more recently issued maps of Cader Idris the igneous rocks occurring upon the lower horizons of the mountain are coloured as entirely intrusive. The section, however, published by the Geological Survey in 1852, and copies of the map prior to 1881, correctly represent them as consisting largely of ashes, and in the section they are included in the old extensive Lingula Flags.

The presence of the Lower Tremadoc beds upon the flanks of Mynydd-y-Gader is well shown by Belt †, who records the discovery of *Niobe Homfrayi* and *Asaphus innotatus*, accompanied by fossils recalling the earlier Cambrian fauna. Beneath these beds he recognized the "Dolgelly Group" of the Lingula Flags ‡. Mr. Homfray, of Portmadoc, who went over the ground with Belt, informs us that the junction of the Tremadoc and the Arenig is obscured by the intrusive masses; but he states that the Tremadoc beds lie upon the top of Mynydd-y-Gader, the ironstone, with characteristic Trilobites above it, occurring near the base of the Arenig and being included in that group. This correlation has been accepted by the author of the Survey memoir and by subsequent writers, who regard the ironstone as the representative of the similar bed at Pen-y-morfa, and who indicate in their sections a considerable thickness of Tremadoc strata between it and the crest of Mynydd-y-Gader, or on corresponding horizons of the mountain §. It is clear, then, that the series described by us as slaty tuffs and metamorphosed ashes coincides in large part with the beds accepted

* Dr. Hicks, in 1875, in discussing the conditions under which the Cambrian and Silurian rocks were deposited, places the commencement of eruption at the close of the Arenig period. Quart. Journ. Geol. Soc. vol. xxxi. p. 558.

† Geol. Mag. 1868, p. 8.

‡ *Ibid.* 1867, p. 542.

§ Mem. Geol. Survey of Gt. Britain. vol. iii. 2nd ed. pp. 35, 38, 39, &c. Hicks, Congrès Géol. Internat. Londres, 1888, Explication des Excursions, fig. 16.

as Tremadoc. Some of the characteristic ashes of Mynydd-y-Gader, occurring on its north-west flanks seven hundred feet below the summit, may even fall within the "Dolgelly Group" of Belt.

If, indeed, we are to include all the eruptive deposits in the Arenig, the black slates of the Penrhyn-gwyn quarry, lying as they do beneath the first slate-tuff, must represent the uppermost Tremadoc; but these occur 600 feet nearer the sea-level than the summit-beds of Mynydd-y-Gader, and we have to face the fact that, taking the average dip as only 20°, a thickness of some 2200 feet of ash and slate and intercalated sheets intervenes between Penrhyn-gwyn and the horizon of the Arenig ironstone near Llyn-y-Gader. Even if this thickness is deceptive, even if it is the result of a series of repetitions by localized strike-faults, the evidence of the fossils on Mynydd-y-Gader is in no way vitiated.

It is of course difficult to compare the thickness of normal sediments with those formed contemporaneously near an active volcano; but we feel that, until those best qualified to judge extend the local base of the Arenig to the northern front of Mynydd-y-Gader, we must regard a large portion of the eruptive series as of Upper or even Lower Tremadoc age.

Thus the great eruptions commonly referred to the Arenig and Llanvirn periods, or the Llandeilo of older writers, would seem to have actively broken out in pre-Ordovician times. The products of the volcanic vents in the neighbourhood of Cader Idris became more and more highly silicated during the Arenig period, and thus afford an early indication of the conditions that afterwards prevailed throughout North Wales, when the exceptionally glassy lavas of Bala age must have rivalled, over miles of country, the obsidians of the Yellowstone Park. While the intrusive sheets, with the exception of the eurite, are of more basic character than the ashes which are penetrated and altered by them, they none the less appear to belong to much the same period of activity. Like the well-known instances in the Jurassic strata of the east of Skye, they have followed the planes of bedding with remarkable uniformity. It would seem, indeed, that these sheets are lateral offshoots from some fairly distant centre, and that they were injected between beds already weighted with superincumbent sediment. The contrast between the structure thus produced and that formed by dykes on the flanks of a volcano is very marked upon the northern slopes of Cader Idris.

But these intrusive sheets are not found in the undoubted Llandeilo strata towards Machynlleth, and the facts of their distribution connect them distinctly with the activity that culminated in Arenig times. It is quite possible that they represent a reversion towards basic conditions at a time when the mass of material already erupted prevented further action at the surface, and spread out these dolerites and aphanites along easier planes of passage underground.

So far as we have at present examined the evidence afforded by Rhobell-fawr, the rocks of that most interesting cone, ranging from hornblende-dolerite to basic scoriæ, do not seem to point to its

connexion with either the tuffs or the intrusive sheets of Cader. The mapping of this rugged area as one continuous mass of intrusive "greenstone" has doubtless led many besides ourselves to mentally exaggerate its importance before becoming acquainted with it in the field. Its composite character is, however, referred to in the careful Survey memoir.

It may be that the volcanic action in the Cader Idris district was almost entirely explosive, and that the actual vent has been lost amid the distribution of its products by the sea. That local unconformities on an appreciable scale must have been produced, is shown by the ejected sedimentary flakes in which the tuffs abound.

The age of the eurite itself can only be inferred from the character of the lava-flows of middle Ordovician times. Just as the intrusive masses at Mynydd Mawr and other points round Snowdon may represent the centres from which the Bala rhyolites flowed, so this enormous sill may have been connected with the acid eruptions of which we have evidence among the Llandeilo slates of Craig-y-Llam. It may even be possible to trace on the southern slopes of Cader, or at some point further to the north-east, the continuity of part of the eurite with these products of surface-eruption.

It is interesting to note, in conclusion, that the intrusive granite between Ffestiniog and the Moelwyn range, with its abundant quartz and its poorness in ferro-magnesian silicates, is just such a rock as might have resulted had more complete crystallization, under slower conditions of cooling, taken place in the eurite of Cader Idris *.

In preparing the notes here brought together, we have several times received generous assistance from Mr. G. J. Williams, F.G.S., whose intimate knowledge of Ordovician strata in North Wales is always at the service of his friends. We are also indebted to Prof. J. W. Judd, Mr. D. Homfray, and Dr. Hicks, for kind help given and the removal of some of the difficulties that we have met with. We feel that the stratigraphical questions raised in the concluding section of this paper can only be settled by detailed mapping and correlation of the several fossiliferous horizons. We have sought to show, however, that contemporaneous volcanic rocks form a large part of Cader Idris at a level far below that assigned to the base of the Arenig.

Discussion.

The President was struck by the fact that the crystalline volcanic beds appeared to be intrusive, the tuffs only being contemporaneous. Some years ago Mr. David Forbes had argued that a submarine lava-flow was impossible. He believed that this view had not been universally accepted, but he thought it might account for the great thickness of many submarine tuffs.

Dr. Hicks said, with regard to the volcanic series, that it was not quite certain what Tremadoc beds were found in the region; the

* This granite has been described by Mr. Teall in his 'British Petrography,' p. 319.

Tremadoc fossils which had been discovered were rather Upper than Lower Tremadoc. He had published a paper in which he maintained that the so-called Upper Tremadoc rocks of Caernarvonshire should be classed as Arenig. In these there was a considerable amount of volcanic material. It was yet doubtful how frequently volcanic outbursts had occurred in the region; the Harlech Beds of the Harlech anticlinal and the Menevian beds contained materials indicative of contemporaneous volcanic action, and similar conditions to those of North Wales occurred in the St. David's region. The same was the case in the succeeding series. In the rocks of the Arenig mountains there was a climax to the volcanic action.

Prof. Blake hinted at the occurrence of lavas in the Cader Idris district, from evidence derived from an examination of loose blocks.

Mr. Rutley commented on the difficulty of distinguishing between lavas and ashes after induration. He referred to Daubeny's observations on submarine volcanoes; that author considered such lavas could never be glassy and never vesicular. Nevertheless, such had actually been found so formed.

Mr. Cole replied to Dr. Hicks that there were undoubted tuffs at the lower levels of the mountain. Their age must be left to future investigation into the stratigraphical geology of the area; but the statements made in the paper were founded on prevailing opinion. It was possible that the Tremadoc Beds might be faulted out. The old Survey sections were fairly accurate. The scoriaceous rocks were sometimes intrusive, though many of the tuffs were also scoriaceous. Nowhere on Cader Idris were there such coarse tuffs as in the Snowdonian district.

29. *On the* Cotteswold, Midford, *and* Yeovil Sands, *and the* Division *between* Lias *and* Oolite. By S. S. Buckman, Esq., F.G.S. (Read February 20, 1889.)

It has been observed that attention to lithology is likely to insure success in the matter of correlation. I am bound to confess, however, that my experience of Jurassic rocks tells me that in many cases this observation is quite incorrect. Within the limits of one basin it may happen that the same horizon can often be identified by the similarity in lithology; but even within such limits it certainly will not be safe to place much reliance on such a guide; while in correlating the strata of one basin with those of another, such an idea will probably lead to very decided errors. The strata now to be discussed have suffered singularly in the matter of correlation from this similarity of lithology.

In the counties of Dorset, Somerset, and Gloucester there occur in most places, between clay of Upper Liassic age and limestone of the Inferior-Oolite period, certain yellow micaceous sands, which contain, at intervals, in some places regular bands, in others lines of more or less lenticular masses, of a hard, greyish, sometimes blue-hearted, sandstone. Among other local names, these sandy strata have been known in the county of Gloucester as Cotteswold Sands, in North Somerset as Midford Sands, in the county of Dorset and in South Somerset as Yeovil Sands. On account, however, of the similar position which they occupy with regard to Lias clay and Inferior-Oolite limestone, and also, no doubt, on account of their exactly similar lithological appearance, the name "Midford Sands"* (a name first applied by William Smith to the sands at Midford) has been used to designate these sands in the three counties; under this name they have been mapped by the Geological Survey.

Around the sands which lie between Liassic clay and Oolitic limestone a constant discussion has been waged for the last thirty years or more, as to whether they should be classed with the Liassic or Oolitic periods. According to the opinion of those whom I may call the first generation of geologists, whose pioneer was William Smith, the sands were "Sands of the Inferior Oolite." The celebrated Dr. Oppel, who visited this country about 185?, comprehended the positions of these sands with his usual acute perception; and had our English geologists given to his work the attention which it deserves, it ought to have been impossible for the discussion to have been maintained. In 1856 Dr. Oppel, in the 'Juraformation,' p. 296, places the Cotteswold Sands of Frocester Hill in "the zone of *Posidonomya Bronni*," that is, with the Upper Lias; while on the

* In the following paper the term "Midford Sands" written thus, means that it is used in the same sense as by the Officers of the Geological Survey; while Midford Sands refers only to the yellow micaceous sands round Bath, Midford, &c.

other hand, at p. 253, he states that at Ilminster the sands of the Inferior Oolite (that is the Yeovil Sands) begin above a bed filled with *Amm. jurensis*, *discoides*, *radians*, &c. Here we have the keynote of the whole affair, published more than thirty years ago. Dr. Oppel saw that the Cotteswold Sands and the Yeovil Sands are on two entirely different horizons; and actually placing the one series in the Lias and the other in the Inferior Oolite, he located between them the zone of *Amm. jurensis*. Yet, in spite of what Oppel had written, the position of the "Sands" remained a bone of contention for very many years, and but little notice was taken of his statements.

It was also in the year 1856 that Dr. Wright proposed* to assign to the Upper Lias those Yellow Sands of Gloucestershire, Somerset, and Dorset which had, from the time of William Smith, been classed as "Sands of the Inferior Oolite." With them he also united the marly-limestone cap which overlies them in the former county, and which is now known as the Cephalopoda-bed of Gloucestershire. Finding that the Sands of Dorset reposed beneath a similar lithological cap, he considered this also to be on the same horizon; and thus it came to pass that he included in the Upper Lias the *Murchisonæ*-zone, the *Concavum*-beds, and even part of the *Parkinsoni*-zone of the Bradford-Abbas and Halfway-house strata. It is instructive to notice the species of Ammonites which he quotes, from the so-called Upper-Lias Cephalopoda-bed of Bradford Abbas, in support of this view, p. 310:—

1. Ammonites jurensis, *Zieten*.
2. ,, concavus, *Sowerby*.
3. ,, dorsetensis, *Wright*.
4. ,, variabilis, *d'Orbigny*.
5. ,, striatulus, *Sowerby*.
6. ,, insignis, *Schübler*.

Because we know, at the present day, that of these six species the identification of five must have been incorrect, while the one whose identification is correct—*A. concavus*—happens not to be an Upper-Lias Ammonite at all. The correct names of the others are the following:—

1. Lytoceras confusum, *S. Buckm.*
3. Parkinsonia Parkinsoni (*Sowerby*).
4. Sonninia, sp.
5. Dumortieria grammoceroides, *Haug*.
6. Hammatoceras amaltheiforme (*Vacek*), or a near ally.

In 1860 Dr. Wright † removed the Bradford-Abbas beds from this position to place them, also incorrectly, in the *Humphriesianum*-zone, and then noticed the existence of another bed on the horizon, as he supposed, of the Gloucestershire Cephalopoda-bed. This bed, together with the sands, he classes as "Upper Lias Sand-zone of *A. jurensis*." This opinion remained practically unchanged.

* "The Palæontological and Stratigraphical Relations of the so-called Sands of the Inferior Oolite," Quart. Journ. Geol. Soc. vol. xii. p. 292 (1856).
† "Inferior Oolite," Quart. Journ. Geol. Soc. vol. xvi.

The only difference was that the upper part of the Frocester-Hill Cephalopoda-bed was placed in the zone of *A. opalinus;* while the Sands were sometimes spoken of as part of the zone of *A. bifrons*, at other times as the zone of *A. jurensis* *: all were included in the Upper Lias.

The chief opposition to the above views came from my father †, who first of all considered the Cotteswold Sands as equivalent to the Freestones of the Cheltenham district, but at a later date placed the Yeovil Sands in this position, the Cotteswold Sands being allowed to go to the Upper Lias because their position was altogether below that of the Yeovil Sands. This view of the different positions of the Cotteswold and Yeovil Sands is noticeable, for it coincides closely with Oppel's; and it is clearly set forth in a diagram of the Midford Sands compared with Haresfield ‡.

To the sands which throughout the greater part of England lie between Liassic clay and Oolitic limestone, Prof. Phillips § extended Smith's name and applied the term "Midford Sands;" although he placed them in the Liassic period, he considered them as Transition Strata. H. B. Woodward, in the first edition of his standard work ||, restricted the term "Midford Sands" to the counties of Dorset, Somerset, and Gloucester, and attached them to the "Oolitic." Lately (1887), in the second edition (p. 285), he places them in the "Inferior Oolite Series," considers them transitional, and defines them as follows:—

	"Zones.
Midford Sand.	Ammonites (Harpoceras) opalinus.
	„ (Lytoceras) Jurensis."

Such is the position of affairs at present, and thus the name "Midford Sands" is in common use for the Yellow Sands of Gloucestershire with the overlying Cephalopoda-bed, for the Yellow Sands of North Somerset, and for the Yellow Sands and shelly Sandstones of South Somerset and Dorset ¶. Now the questions arise, Do these series of Sands begin on the same horizon, and, including the Cephalopoda-bed, do they end on the same horizon? How much of this horizon is found at Midford? Do the limits of the *Opalinum*- and *Jurense*-zones correspond with the limits of the Sands; or do they not go above and below them in some cases, and not reach the bottom in others? Are the sands all on one horizon, as stated by Wright; or are they on two different horizons, as Oppel and my father thought?

We must appeal to the Ammonite-fauna; and having by means of that fauna selected a definite horizon as a fixed point, it will be

* "Lias Ammonites," Palæont. Soc. p. 137 *et. seq.* (1879).

† "The Oolites," Quart. Journ. Geol. Soc. vol. xiv. p. 106; also "The Cephalopoda-bed," Quart. Journ. Geol. Soc. vol. xxxiii. p. 3.

‡ "On the so-called 'Midford-Sands,'" Quart. Journ. Geol. Soc. vol. xxxv. p. 738 (1879).

§ Geology of Oxford and Valley of Thames, p. 118 (1871).

|| The Geology of England and Wales, p. 166 (1876).

¶ H. B. Woodward, *op. cit.* 2nd ed. p. 287.

possible to compare the strata of the different localities therewith, to see if they fall contemporaneously, or above or below the fixed horizon.

The series selected is that of the *Striatulum*-beds, which are traceable in the Cotteswold, Midford, and Dorset-Somerset* districts. In the following sections the top of the *Striatulum*-beds is the point from which one section should be compared with another.

Frocester Hill is almost the northernmost point at which the *Striatulum*-beds appear; at Haresfield Beacon they are practically absent, and at Leckhampton only the very top of the Cephalopoda-bed is seen resting on sands. The following section, taken at Buckholt Wood, which is a short distance north of the well-known Frocester-Hill section, gives the Cephalopoda-bed (the Limestone capping of the Cotteswold Sands) in fairly full development.

I. *Section at Buckholt Wood.*

			ft.	in.
Cephalopoda-bed.	*Moorei*-beds.	1. Brownish limestone with darker brown grains. *Dumortieria Moorei* (Lycett); *Dum. subundulata* (Branco); *Dum. sparsicosta*, Haug; *Grammoceras mactra* (Dumortier); *Rhynch. cynocephala*; *Terebratula haresfieldensis*; *Belemnites*	1	9
	Dumortieria-beds.	2. Yellowish; but more often dark grey, almost black mudstone with dark brown grains. Ammonites scarce and badly preserved. *Dum. rhodanica*, Haug; *Rh. cynocephala*; *Terebr. haresfieldensis*	2	0
		3. Reddish-yellow, somewhat sticky, gritty marl; in places numerous *Belemnites*		6
	Dispansum-beds.	4. Dark grey, ironshot, soft stone breaking up into shales. *Gramm. dispansum*, *Hamm. insigne*, *Astarte*, sp.	1	0
		5. Marl		2
	Striatulum-beds.	6. Light yellow, soft stone. *Dumortieria rhodanica*? *Gramm. dœrntense* (Denckmann), *Gramm. striatulum* (Sowerby)		9
		7. Brownish marl, numerous dark brown grains. *Grammoceras*, sp., involute		7
		8. Yellowish stone with brown grains. *Gramm. striatulum* abundant, *Haugia Eseri*		6
		This bed lies above and fills the interstices of the very uneven-topped		
Cotteswold Sands.	*Variabilis*-beds.	9. Hard, blue-hearted sandstone	1	3
		10. Yellow micaceous sands		

This section does not exhibit the Cotteswold Sands, and in order to obtain an exposure of them we must go to Coaley Wood; but it displays certain features connected with the Cephalopoda-bed in a better manner than Coaley. The following Section has already appeared in my monograph on Inferior Oolite Ammonites (Pal. Soc. 1887, p. 45); but it is here reproduced with some additions and alterations.

* The district south of the Mendips is thus designated.

II. *Section at Coaley Wood.*
(1½ mile from Section I.)

			ft.	in.
Ragstone.	*Parkinsoni*-zone.	1. Ragstone with *Terebratula globata.*		
Freestone.	*Murchisonæ*-zone.	2. Deep Freestone quarry.		
Sandy ferruginous Limestone.	*Opalinum*-beds ?	3. Pale-yellow stone, with light-coloured oolitic grains. About	5	6
	Opalinum-beds.	4. Very hard, pale-coloured compact rock, with very small brown grains; gives a metallic ring when struck. *Lioc. opalinum* fairly abundant; hardly any other fossils	1	4
Cephalopoda-bed.	*Moorei*-beds.	5. Hardish, somewhat irregular, yellowish rock (with more brown grains, but not so compact as 4). *Lioc. opalinum*; *Lytoc. Wrighti*, S. Buckman; small *Chemnitzia*; *Belemnites*, &c.		6
		6*. Rubbly, oolitic, irregular stone, like 5; hardly separated from it, but softer, and mixed with marl. *Lytoc. torulosum*; quantity of *Belemnites* and *Astarte*; also *Opis*, *Cypricardia*, and many *Lamellibranchiata*, *Lytoceras Wrighti* ...		8
	Dispansum-beds.	7. Hard, compact, pale yellow stone, with darker grains. *Gramm. fallaciosum*, *Gramm. dispansum*, *Gramm. dœrntense*, *Pseudolioceras compactile*, *Oxynoticeras?* *discoides*, *Hammatoceras insigne*		6
	Striatulum-beds.	8. Brown rubbly marl, with numerous dark-brown grains; looks like crushed linseed. *Gramm. striatulum*, *Gramm.* sp., *Haugia Eseri*		7
Cotteswold Sands.	*Variabilis*-beds.	9. Very hard, bluish-grey, sandy, nodular-shaped lumps imbedded in the marly paste of the bed above	0	2–3
		10. Hard, blue-centred stone		6
		11. Fine, yellow, micaceous sands, about	50	0
		12. Brownish, concretionary rock, very slightly micaceous, containing dark oolitic grains and pieces of broken shells; has a similar appearance to Bed 7, but is harder. Some Ammonites; but they are scarce	2	9
		13. Two bands of hard, yellowish-blue, somewhat sandy stone. Large *Limæ*; *Haugia* sp., &c.	2	0
		14. Yellow sands, becoming blue in the lower part.	10	0
		15. Dark yellowish-brown, concretionary marl with Ammonites.		3
		16. Band of yellowish-blue, hard, sandy stone. Ammonites fairly abundant, especially on the top. *Haugia variabilis*, *Lytoceras sublineatum*, *Dactylioceras crassum*		9
		16 *a*. Fine yellow sands, about	25	0
	Commune-zone.	17. Band of yellowish-blue, hard sandstone. *Hildoceras bifrons*, abundant; *Pseudolioceras compactile*	1	0
		18. Yellow sands, visible for some feet, and conjectured to extend down to the spring of water	40	0
Upper Lias.		19. Blue Clay ?		

* This was, by oversight, in my Monograph, Pal. Soc. vol. xli. p. 45, relegated to the *Striatulum*-subzone. The lettering shows this is an error. No. 7 should have been so designated, and marked C^1.

The next section shows how the *Dumortieria*-beds have expanded; it also gives a very clear account of the Sands, especially with the addition of the roadside cutting at Stinchcombe. These sections, III. and III. A, appeared in my Monograph (pp. 46, 47).

III. *Section at Nibley Knoll.*
($3\frac{1}{2}$ miles from Section II.)

			ft.	in.
Ragstone.	*Parkinsoni*-zone.	1. *Trigonia*-grit and rubble	5	0
Freestone.	*Murchisonæ*-zone ?	2. Pale-coloured freestone with white oolitic grains. Occasional dark brown bands	25	0
		3. Freestone imperfectly shown, about	10	0
Sandy ferruginous Limestone.	*Opalinum*-beds ?	4. Pale, somewhat sandy rock, very slightly oolitic; imperfectly shown. *Pholadomya fidicula*, *Trigonia striata*, *Astarte*. About	8	0
	Opalinum-beds.	5. Band of pale, slightly oolitic rock, with irony grains	1	2
Cephalopoda-beds.	*Moorei*-beds.	6. Light-yellow, rubbly marl with irony grains. *Lioc. opalinum*, *Gramm. Steinmanni*, *Hammatoceras* sp.		9
		7. Band of rock. *Rhynch. cynocephala*		8
	Dumortieria-beds.	8. Yellowish-grey, clayey marl	1	0
		9. Yellow marl, oolitic, somewhat concretionary	1	2
		10. Yellow and yellowish-grey marly shales, many dark oolitic grains. *Dumortieria rhodanica*	3	6
		11. More concretionary marl. *Catulloceras Dumortieri*	2	6
	Dispansum-beds.	12. Much the same as 10. *Gramm. dispansum*	1	2
	Striatulum-beds.	13. Hardish, yellow, oolitic rock. *Gramm. striatulum*, *Hamm. insigne*	1	0
		14. Dark-brown, oolitic paste; looks like crushed linseed. *Gramm.* sp.		7
		15. Hard, irregular rock in two layers. *Gramm. striatulum*, abundant; *Lytoceras jurense*, *Haugia Eseri*	1	2
Cotteswold Sands.	*Variabilis*-beds.	16. Fine, yellow sands, harder at the top; perhaps divided by concretionary layers, but none such visible; about	60	0
		17. Yellowish-brown, concretionary, sandy layer; no fossils		9
		18. Hard, bluish-yellow, slightly sandy rock. *Belemnites*, *Turbo*, *Amberleya*, *Lima*, &c.		7
		19. Fine yellow sands		10
		20. Yellow, sandy stone; only one small species of *Haugia*, poorly preserved		6
		21. Yellow sands	5	0
		22. Band of yellow, sandy stone		4
		23. Yellow sands	3	0
		24. Band of yellow, sandy stone		7
		25. Yellow sand	7	0
		26. Band of yellow, sandy stone		4
		27. Yellow sand	3	6
		28. Band of blue-centred sandy stone. *Haugia variabilis*, *H. Ogerieni*, *Pseudol. compactile*, *Dactyl. crassum*, *Belemnites*, &c.		6
		29. Yellow sands	6	0
		30. Band of blue-centred sandy stone. *Lytoc. sublineatum*, *Pseudol. compactile*, *Haugia Ogerieni*, *Dactyl. crassum*, *Nautilus Jourdani*		6
		31. Blue and yellow sands (for continuation see next section); about	30–35	0

III. A. *Section in the road at Stinchcombe.*
(May be considered as a continuation of the preceding Section.)

			ft.	in.
Cotteswold Sands. Upper Lias.	*Commune*-zone.	31. Yellow sands		
		32. Very dark-brown, argillaceous marl. *Hildoceras bifrons, Pseudolioceras lythense, Belemnites,* &c.		1
		33. Brownish, and sometimes bluish, shelly, somewhat sandy stone, with plenty of small ferruginous specks; top part very uneven, and filled with the bed above. *Hild. bifrons, Dactylioceras, Rhynchonella, Terebratula,* &c.		8
		34. Dark-blue clay, without fossils, containing large blue-hearted nodules of stone which break with a conchoidal fracture and are non-oolitic.		

The next section is remarkable for the fact that a great change of lithology takes place. Instead of being oolitic marl or limestone as in the previous sections, the *Dispansum*- and the *Striatulum*-beds are now yellow and grey sands with bands of sandstone. The thickness of the sands also has much diminished; but the thickness of the *Dispansum*- and *Striatulum*-beds is much increased, simply owing to the prevalence of sandy conditions.

IV. *Section at Little Sodbury.*
(8 miles from Section III.)

			ft.	in.
Freestone.		1. Whitish limestone, with numerous white grains.		
Sandy ferruginous limestone.	*Opalinum*-beds?	2. Straw-coloured, shelly, sandy limestone, about	2	0
		3. Reddish-brown, very hard, ironshot limestone, about	1	0
Cephalopoda-bed.	*Moorei*-beds.	4. Greyish, much ironshot marl; in some places softer, in others harder. *Rhynch. cynocephala, Dumortieria Moorei*	4	6
	Dumortieria-beds.	5. Darker, soft mudstone, much ironstone. *Dumortieria rhodanica, Rhynch. cynocephala, Chemnitzia procera*	2	6
		6. Grey ironshot marl	3	0
Cotteswold Sands.	*Dispansum*-beds.	7. Grey sandstone. *Lytoc. Germaini,* fragment		4
		8. Yellow and grey micaceous sands	8	0
	Striatulum-beds.	9. Hard, yellowish, somewhat ironshot stone. *Gramm. striatulum*		10
		10. Grey marl	1	2
		11. Much ironshot marl and mudstone with "*Gramm.* sp., involute"		8
		12. Grey, shelly sandstone, some few brown oolitic specks. *Gramm. striatulum, Haugia occidentalis*	1	6
		13. Yellow sands. *Gramm. striatulum* towards the top	2	0
		14. Grey sandstone. *Gramm. striatulum*		4
		15. Greyish sands	2	6
		16. Grey sandstone. *Gramm. striatulum*		9
		17. Yellowish sands	4	0
		18. Yellow sandy stone. *Gramm. striatulum,* with very coarse ribs	1	8
		19. Yellow sands, a few inches only visible.		

There are about 15–20 feet more before the Clay is reached, but being unexposed it cannot be said if any hard bands are contained therein, or what Ammonites.

Pseudol. compactile was found in a block of fallen sandstone.

Lyncombe. The following section was brought to my notice by the kindness of the Rev. H. H. Winwood, F.G.S., with whom I visited the spot. He also made some notes of this section when the line was first opened and I refer the reader to them *.

The most remarkable feature in the Section is probably a point now noticed for the first time, namely, that one single block of stone, only 1 foot 7 inches thick, contains portions of three different zones, and exhibits three different bands of matrix firmly cemented together †.

Brown, coarse, oolitic stone, 5 inches.	*Striatulum*-beds; *Jurense*-zone.
Brown, oolitic stone, not so coarse in texture, 4 inches.	*Commune*-zone.
Bluish-grey stone with a soapy feel, non-oolitic, 10 inches.	*Falciferum*-zone.

The attenuation of the *Commune*-zone is very great, and not improbably careful research would show some admixture of its species with those of the *Striatulum*-beds above. The other two zones extend, one above—*Jurense*-zone, *Dispansum*-beds—the other below—*Falciferum*-zone, Blue Clay.

Another point to be noticed in this Section is that the Yellow Sands have ascended one stage higher. They do not, as at Sodbury, envelop the strata known as the *Striatulum*-beds, but they begin above them. Consequently the next series (that of the *Dispansum*-

* "Notes on some Railway Sections near Bath," Proceedings of the Bath Natural History and Antiquarian Field Club, vol. iii. no. 2, p. 129 (1875).

† I had, not long previously, discovered a similar, but perhaps more extraordinary, instance of the same feature. At a small quarry on Lodge Hill, just south of Castle Cary, Somerset, the lower part of the *Parkinsoni*-zone is cemented firmly to Sandstone of the Yeovil Sands (*Opalinum*-zone); and the mass comes from the quarry as one piece of stone exhibiting two bands of very different matrix, thus:—

Brownish oolitic limestone, 3 inches.	*Parkinsoni*-zone.
Bluish-grey, hard, gritty sandstone, 8 inches.	*Opalinum*-zone.

This is the more remarkable when we consider that the time of formation of the *Murchisonæ*- to the *Humphriesianum*-zones inclusive had elapsed between the deposition of the upper and lower of these two bands.

beds) is very much thicker than before. It is not known at present if any higher horizon is included in the upper part of the Sands; but it is possible.

V. *Section exposed in Greenway Lane and Lyncombe cutting, near Bath; Somerset and Dorset Railway.* (14 miles from Section IV.)

			ft.	in.
Inferior Oolite.	*Parkinsoni*-zone.	1. Yellowish oolitic limestone. *Tereb. globata, Rhynch. spinosa*, &c.		
Midford Sands.	Uncertain.	2. Yellow micaceous sands not well exposed, about ...	65	0
	Dispansum-beds.	3. Yellow sands with about a dozen lines of "Sand-burrs." From fallen "Sand-burrs" *Gramm. fallaciosum* was obtained	35	0
Junction beds.	*Striatulum*-beds.	4. Yellowish-brown stone, with very numerous lighter-coloured oolitic grains which fall out and leave the stone pitted. *Gramm striatulum.*		5
		This is firmly cemented without a break on to		
Upper Lias.	*Commune*-zone.	5. Yellowish stone with the oolitic grains less numerous, and therefore appearing of a closer texture. *Hild. bifrons, Dactyl. Holandrei, Dactyl. crassum, Waldheimia Lycetti, Rhynchonella*, sp.		4
		This is firmly cemented without a break on to		
	Falciferum-zone.	6. Close-grained, smooth-feeling, greyish-blue stone, without any trace of grains as in the bed above. *Harpoceras falciferum*		10
		7. Greyish-blue clay		6
		8. Close-grained, greyish, mottled stone		4
		9. Greyish-blue clay		

The above section is superior, for our purpose, to the one exhibited at Midford. Considering that it is only about a mile and a half from Midford it may be taken as a thoroughly representative Section of Midford Sands joining Lias Clay.

The next Section, that of the classic locality of Ham Hill, in Somerset, is very interesting from a geological point of view, but wholly disappointing palæontologically. The large mass of freestone and sandstone (both composed of comminuted and crushed shells, among which *Rhynch. cynocephala* or (?) *Beneckei* * occurs), preceded and followed by yellow micaceous sands, is, without much doubt, on the same horizon as the similarly-composed band at Stoford, and probably only an altered condition of the upper part of the Yeovil Sands as seen at Babylon Hill. My father was the first to point this out †; and the opinion has been confirmed by H. B. Woodward ‡. Therefore the Geological Survey has erred in mapping Ham Hill as different from the "*Mid-*

* See Davidson, "Brach.," Pal. Soc., Appendix to Supp. pl. xx. figs. 8, 9, 10 (1884).

† "Cephalopoda-bed and Oolite-Sands," Extract Proc. Somerset Arch. Soc. vol. xx. p. 13 (1874). "The Ceph. beds of Gloucester, Dorset, and Somerset," Quart. Journ. Geol. Soc. vol. xxxiii. p. 5 (1876).

‡ "Note on the Ham Hill Stone," Proc. Bath Ant. Field Club, p. 184 (1887).

ford Sands." The true position of the Stone-beds is probably that horizon of the *Opalinum*-zone which I have designated *Moorei*-beds. In this connexion it is interesting to notice that a *Dumortieria*, probably referable to *Dum. rhodanica*, was met with in the Yellow Sands below, and also that the shell-bed at Stoford contains exactly the same Ammonites as the *Moorei*-beds of Buckholt Wood and other Cotteswold localities.

VI. *Section at Ham Hill.* (37 miles from Section V.)

			ft.	in.
Marked as Inferior Oolite on the Ordnance Survey Map.	*Moorei*-beds.	1. Fine yellow Sand	10	0
		2. "Waste" or "riddings." Occasional layers of stone mixed with layers of yellow sands. The stone is full of comminuted shells. It is generally buried in the quarry, unless wanted for rough work	30	0
		3. Best freestone in immense blocks, a mass of comminuted shells imbedded in a sandy matrix; it is sawn and worked for elaborate designs	50	0
		4. "Bottom Bed." Hard sandstone	1	6
Yeovil Sands.	*Dumortieria*-beds.	5. Yellow micaceous sands with irregular bands of hardened sand-rock at irregular intervals of every few feet. Some isolated lenticular masses of sandstone occur. Thickness about...	55	0
		6. Sand-rock containing a fragment of *Dumortieria rhodanica*		10
		7. Yellow, micaceous sands as in 5. Thickness about	35	0

These Yellow Sands were observed in the lane leading from Montacute to the top of the Hill. They seem to begin just above Montacute Church and to continue the whole distance. A few yards then brings one to the freestone-quarry measured, which, it will be seen, extends 90 feet in depth. It would therefore seem as if the freestone had been let in by a fault, something like 85 feet. The "Bottom Bed" crops out in the lane near some fir trees; while on the opposite side of the road there is a quarry of rough stone evidently faulted down.

I beg to express my thanks to the Director-General of the Ordnance Survey, who very kindly gave me the height of Ham Hill. It is about 90 feet above Montacute church.

The next section is important, because it exhibits the junction of the Yeovil Sands with Upper-Lias Clay. It is noticeable that now the yellow micaceous sands do not begin until we have finished with the *Dispansum*-beds; while the Upper-Lias Clay is here exactly contemporaneous with the Cotteswold Sands, together with the two lower divisions of the Cotteswold Cephalopoda-bed.

VII. *Section at White Lackington Park near Ilminster, Somerset.* (6½ miles from Section VI., West.)

			ft.	in.
Yeovil Sands.		1. Yellow micaceous sands, becoming browner towards the bottom		
Junction bed.	*Dispansum*-beds.	2. Arenaceous marl-bed, somewhat decomposed, brown and light yellow; occasional pockets of bluish-grey argillaceous marl. (This bed is apparently a mixture of No. 1 with the decomposition of No. 2.) *Lytoc. jurense, Lytoc. Germaini, Lytoc. rubescens, Pelecoceras serrodens, Hammatoceras insigne, Oxynot. discoides*; fragment of *Gramm. dispansum*; fragment like *Gramm. striatulum*		2
Upper Lias.		3. Yellowish-grey, soft stone, somewhat sticky, soapy feel. *Oxynot. discoides, Hamm. insigne*		9
	Probable position of *Striatulum*-beds.	4. Bluish-grey tenacious clay with occasional nodules. No fossils found.		

The next Section shows the Lithology and Fauna of the Upper part of the Yeovil Sands in the Yeovil district.

VIII. *Section at Stoford *, Somerset.* (6 miles from Section VI., East.)

About thirty feet below the Inferior Oolite Limestone, and separated therefrom by that amount of more or less unfossiliferous yellow sands, occurs a rich shell-bed, in appearance not unlike the Ham-Hill stone, but less sandy, and with the shells not so much comminuted. This bed is about two feet thick; it is used for building-purposes.

Several years ago my father † and myself obtained as the result of our different visits the following fossils :—

Moorei-beds ‡.

Dumortieria Moorei (Lyc.).
Grammoceras mactra (Dum.).
Dumortieria subundulata (Branco).
Trigonia literata, Young and Bird.
Pecten demissus, Phillips.
Astarte elegans, Sowerby, var.
Ceromya bajociana, d'Orbigny. and many other species.

* See Mr. Hudleston's "Report on Excursion to Sherborne," Proc. Geol. Assoc. vol. ix. No. 4, p. 4 (1885).

† It was from this shell-bed that many of the species quoted in "So-called Midford Sands" (Quart. Journ. Geol. Soc. 1879, p. 743) were obtained.

‡ The sandy strata in the neighbourhood of Bradford Abbas more usually belong to the upper part of the mass of Yeovil Sands. They show various beds of hardened sand-rock isolated from one another by yellow sands. These beds contain *Dumortieria Moorei, Gramm. mactra, Dumortieria subundulata, Dumortieria pseudoradiosa, Dumort. radiosa* var. *gundershofensis, Dumort. Levesquei?, Rhynch. Beneckei.* The absence of the sandy grits with *Lioc. opalinum*, which are found at Burton Bradstock, Stoke Knap, &c., brings the beds into immediate contact with the Inferior Oolite Limestone (*Murchisonæ*-zone), and the so-called "Dew Bed" is probably their uppermost member.

Section IX. (of the interesting exposure at Burton Bradstock) exhibits the junction of Inferior-Oolite Limestone and the Yeovil Sands. With our knowledge of the Cotteswold Cephalopoda-bed we see that we have here a higher horizon than at Bradford Abbas, Stoford, &c.—and a horizon absent from those places. Read in conjunction with the other sections of yellow sands south of the Mendips, we obtain the knowledge that the yellow micaceous sands of this area (the Yeovil Sands) are on exactly the same horizon as the two upper divisions of the Cotteswold Cephalopoda-bed (the *Dumortieria-* and *Moorei*-beds) and also as part of the "Sandy ferruginous Limestone."

IX. *Section at Burton Bradstock.*
(16½ miles from Section VIII., South.)

Made July 5th, 1888, in company with Mr. J. F. Walker, F.G.S., and Mr. J. E. Clark, F.G.S.

			ft.	in.
Inferior Oolite.	*Parkinsoni*-zone.	1. Yellowish oolitic limestone; few fossils. *Parkinsonia Parkinsoni*	4	0
		2. Whitish, shelly, oolitic limestone, glistening with crystal. *Park. Parkinsoni, Waldheimia carinata, Astarte obliqua*	1	7
	Humphriesianum-zone?	*3. Greyish ragstone with many iron grains, somewhat broken up. *Astarte obliqua, Terebratula sphæroidalis,* Gasteropoda. Some iron nodules occasionally: well-marked break		3
	Humphriesianum-zone.	*4. Hard, light brown stone. *Pœcil. cycloides, Terebratula sphæroidalis*		3
		5. Greyish limestone, occasionally stained with iron. *Rhynch. spinosa* at the top, rare. No other determinable fossils	2	0
	Murchisonæ-zone?	6. Irony band, with numerous dark-brown concretionary nodules, and with lumps of limestone with large iron grains		3
	Opalinum-zone.	7. Steel-grey limestone with few iron grains. *Trigonia striata, Lioc. opalinum* and the variety *comptum, Parkinsonia scissa, Rhynch. cynocephala*	1	0
Yeovil or Bridport Sands.		8. Sandy parting. *Lioc. opalinum,* in fragments, *Lytoceras Wrighti?*		3
		9. Irregularly-mixed masses of stone and sand. *Lioc. opalinum,* poor	1	3
		10. Yellow micaceous sands much pierced by worms	2	2
		11. Hard grey sand-rock		7
		12. Yellow sands. *Lioc. opalinum*	1	9
		13. Sand-rock. *Lioc. opalinum*		4
		14. Yellow sands		4
		15. Sand-rock		3
		16. Yellow sands occasionally containing *Lioc. opalinum*	2	8
		17. Sand-rock		
	Moorei- and *Dumortieria*-beds.	18. The yellow sands, with lines of sand-rock, exposed in the cliff. Ammonites are occasionally found in the masses fallen from the upper part, namely, *Gramm. mactra, Catulloceras Dumortieri, Gramm. aalense,* &c. The total thickness of these sands is perhaps	200	0

* It must be from bed 3 or 4 that the following species have been obtained at Burton Bradstock:—*Cosm. Garantianum, Oppelia subradiata, Oppelia Truellii,* var.

At Down Cliffs, about three miles from this locality, we are able to find the continuation of this section, although the exposure is not very good, and I was not able to work it thoroughly.

IX. A. *Section at Down Cliffs, near Seatown, Dorset.*

		ft.	in.
Upper Lias.	18 Yellow sands, a continuation of those seen in the last Section, passing gradually into a		
	19. Blue, somewhat micaceous clay. No fossils were observed. Thickness about	70–80	0
	20. Pink-coloured rock with *Hildoceras bifrons*; attached to a rock like marlstone.		

The first thing which must strike us on examining these sections is the totally different faunas which Nos. III. and VIII. exhibit—sections which show the junction of the so-called "Midford Sands" with Upper Lias Clay. Not one species do they possess in common. The Yeovil Sands (Section VII.) overlie a fossiliferous bed; and if we seek in the section at Nibley for the same fauna which that bed contains, we find it, not below, but above, the Cotteswold Sands. Here we have, to start with, the great and fundamental difference between the position and palæontology of the Yeovil and the Cotteswold Sands. These two little sections (Nos. III. and VII.), both, as it happens, taken from exposures by the roadside, are, after all, the two most important sections in the series. They supply the keynotes to the situation; the others give us general details.

In the first column of the various sections I have placed the usual lithological signification under which the strata have passed. In the second column I have appended certain names to the beds, for the purpose of distinction, taken from some characteristic Ammonite *.

Going through the sections in order, we shall find that the sandy strata continue to begin later, and to end later, in regard to the palæontological evidence as expressed in the second column. Sections II. and III. show us the position of the Cotteswold Sands in the Haresfield-Wotton district, this position being below the *Striatulum*-beds. In the Sodbury district (Section IV.) the sands did not end until the *Dispansum*-beds had been deposited. In the Bath district (Section V.) we do not know the time of the ending of the Midford Sands; but they differ totally from the Cotteswold Sands proper, in that they did not begin until the *Striatulum*-beds had been deposited. In the Ilminster district (Section VII.) the Yeovil Sands did not begin until the *Dispansum*-beds had been laid down, while their ending, as we can find out from Burton Bradstock (Section IX.), from Broad Windsor, and Stoke Knap, occurs towards the top of the *Opalinum*-zone.

* It is not intended to state that the Ammonite of which the name is used is confined to that horizon; but merely that it is most characteristic thereof, that, in fact, it is the dominant species. The word "beds" is used in a different sense to "zone," and is in no way necessarily equivalent thereto. For instance, the *Opalinum*-beds and the *Moorei*-beds are parts of the *Opalinum*-zone.

It may be advantageous to make a thorough comparison of the yellow sands as exhibited in the Cotteswolds, around Bath, and in the Dorset-Somerset area.

Without taking account of the development north of Haresfield Beacon, which seems to be generally unimportant, we may divide this district into two portions :—

I. THE COTTESWOLDS.

A. *The Haresfield-Wotton district.*—Here the sands average about 150 feet in thickness, of light yellow, micaceous, sandy strata, with occasional lines of hardened, bluish-grey sand-rock (sometimes in huge lenticular masses). At the very base is a dark-brown bed, chiefly filled with dwarf specimens of *Hildoceras bifrons* (Stinchcombe). Forty feet from the base occurs a bluish-grey sandstone filled with numerous fine specimens of *Hildoceras bifrons* (compressed variety), and with *Pseudol. compactile* occasionally (Coaley Wood). About 25 feet above this come sundry bands of sandstone &c., with *Haugia variabilis*, *Dactylioceras crassum*, *Lytoceras sublineatum**. Above this come sandy rock-bands (Nibley) with a few Ammonites, among them *Haugia*, sp. The last 50 or 60 feet apparently contain no fossils.

B. *The Sodbury district.*—The sands here are only about 40 feet thick. The lower 15-20 feet are concealed, and their contents could not be ascertained. The upper part contained frequent bands of sandstone, with *Gramm. striatulum*, *Pseudol. compactile*, *Haugia occidentalis*, &c.

II. THE BATH DISTRICT.

The Midford Sands.—These are about 100 feet thick. They are fine, yellow, micaceous sands with numerous lines of small rounded "Burrs"—a greyish calcareous sandstone. The sands rest on an oolitic limestone containing *Gramm. striatulum*. In the "sand-burrs" of the sand just above this bed, *Gramm. fallaciosum* is found (Lyncombe Tunnel). Whether this or anything different is found in the upper part I cannot say, as my researches at Midford were negative in their results.

* At North Nibley two beds, about 40 feet from the base of the sands, and perhaps on a little lower level than the one at Coaley, contain *Haugia variabilis*, *Lytoceras sublineatum*, *Pseudolioceras compactile*, *Dactylioceras crassum*, *Nautilus Jourdani*, &c.

A bed of brown hardened marl in the sands at Chalford and Nailsworth, probably on about the same horizon, contains *Haugia variabilis*, *Dactyl. crassum*, and *Dactyl. mucronatum*.

In the Quart. Journ. Geol. Soc. vol. xvi. p. 5, Dr. Wright states that this bed (his bed *e*) contains *A. jurensis*, *A. insignis*, *A. radians*, and most of the Conchifera of the Cephalopoda-bed which he calls *a*. I particularly investigated this point, which was totally at variance with my experience on the escarpment, and I can positively say it is a mistake, so far as the Ammonites go. The bed in the sands and the Cephalopoda-bed contain only one species in common, viz. *Amm. compactilis*. The Ammonites he quotes are not found in this bed. The distinctness of the Ammonite-fauna at the two horizons is also conclusively shown by an investigation of a collection made by Mr. A. E. Smith of Nailsworth, to whom my thanks are due for liberty to inspect the same and for other information.

III. The Dorset-Somerset District (south of the Mendips).

The Yeovil Sands.—These may be said to average 150 feet in thickness, and are fine, yellow, micaceous sands with frequent bands of sand-rock. They rest on a bed of marl and clay containing *Lytoceras jurense*, *Lytoc. Germaini* ?, *Lytoc. rubescens* ?, *Pelecoceras serrodens*, *Oxynoticeras discoides*, *Hammatoceras insigne*, *Grammoceras dispansum*, fragment, *Grammoceras striatulum*, fragment, *Gramm.* sp. (White Lackington). In the yellow sands are found *Dumortieria rhodanica*, fragments (Ham Hill). Higher up we meet with about 50 feet of fine sandy freestone—a mass of comminuted shells—with *Rhynch. cynocephala* or *Beneckei*. Layers of sand and coarser freestone cover this for some thirty feet; and these, again, are capped by ten feet of fine yellow sands (Ham Hill). These freestone and higher beds are probably represented round Bradford Abbas, Stoford, &c. by bands of sandstone sometimes containing a mass of comminuted shells (see Section VIII.). In these rock-bands *Gramm. mactra*, *Dumortieria Moorei*, *Dum. subundulata*, &c. have been obtained. The topmost bed of the sand-series in this district is a hard blue-centred stone, the "Dew-bed" of Bradford Abbas.

At Broad Windsor, Stoke Knap, and other places, at the upper parts of the sand-series, are sandy grits containing *Lioc. opalinum*, *Terebratula infraoolithica*, *Rhynchonella cynocephala*, *Waldheimia Blakei*, &c. These sandy grits may possibly be partly on the same horizon and partly on a higher horizon than the Ham-Hill stone.

At Down Cliff, near Seatown, the yellow sands repose on a bluish marl passing into micaceous clay. There seemed to be no fossil-bed at the junction, and the blue marl appeared barren. Not improbably the *Striatulum*-beds may be found in this blue clay, possibly near its base. If so, this would be a very important point. At Burton Bradstock about 150 feet of yellow sand is exposed in a fine cliff. From fallen blocks *Gramm. mactra*, *Gramm. aalense*, and *Catulloceras Dumortieri* were obtained. In the road-cutting on the top of the cliff the sand-rock bands of the upper ten feet of the sands are characterized by *Lioceras opalinum* ; so also is the lowest bed of limestone.

From the analysis of the various sand-deposits it will be seen that none of the different districts contain the same Ammonite-fauna. In every district—I. A & B, II., III.—the Ammonites which characterize the sands are not only specifically, but often generically, distinct from those of the others. If we now go back to the first district, and examine the strata which there repose upon the sands—that is, if we examine the so-called Cephalopoda-bed—we shall be able to find out the exact explanation of what these various Ammonites indicate.

The Cephalopoda-bed of Gloucestershire may be said to be fully developed only between the south side of the Stroud valley and Wotton-under-Edge inclusive. It consists of brown marls with dark-brown grains, separated at intervals by layers of hardened oolitic stone. The thickness of the series varies from about eight

to fifteen feet; and it may be divided into four stages. The lowest stage—the *Striatulum*-beds—contains *Gramm. striatulum*, *Gramm. Bingmanni*, *Pseudolioceras compactile*, *Haugia Eseri*, *Haugia illustris*, &c. The stage above this — the *Dispansum*-beds — contains *Gramm. dispansum* abundantly in some places, in others *Gramm. fallaciosum* takes its place; here belong also *Gramm. Sæmanni* (Dumortier), *Gramm. dœrntense*, *Hammatoceras insigne*, *Oxynoticeras discoides*.

The third stage—the *Dumortieria*-beds—obtains its name from the presence of several species of the extraordinary genus *Dumortieria*, of which *Dumortieria rhodanica* is the most abundant. Here also come *Dum. Levesquei*, *Dum. striatulo-costata*, Haug, *Catulloceras Dumortieri*, *Pelecoceras affine*, *Pelecoceras serrodens*, *Terebratula haresfieldensis*, *Rhynch. cynocephala*, &c.

The fourth stage—the *Moorei*-beds—completes the series known as the Cephalopoda-bed. It is characterized by some peculiar species, namely, *Dumortieria Moorei*, *Gramm. aalense*, *Gramm. Steinmanni*, *Gramm. fluitans*, *Gramm. subcomptum*, and occasionally *Lioceras opalinum*. In addition *Hamm. Alleoni*, *Lytoceras Wrighti*, *Dumortieria subundulata*, *Gramm. mactra*, *Terebratula haresfieldensis* and *Rhynchonella cynocephala* are found.

We have now reached the top of the so-called Cephalopoda-bed, and we pass into what was called by Mr. Witchell the "sandy ferruginous limestone" *. The lowest bed of this series is harder and darker than the others, and contains *Lioc. opalinum* in fine proportions, also *Pseudolioc. Beyrichi*, *Ludwigia* sp., &c. The rest of the series up to the white, oolitic "Lower Limestone" may be described as generally light-yellow, sandy, sometimes hardly oolitic stone, containing *Lioc. opalinum*, *Lioceras ambiguum*?, *Hammatoceras* sp., and *Parkinsonia scissa*. The whole of the "sandy ferruginous limestones" may be classed as another stage—the *Opalinum*-beds. They probably form the uppermost portion of the *Opalinum*-zone, and are evidently on exactly the same horizon as the bed of the Burton-Bradstock section.

Now, if we look at this whole series of beds and the fauna which they contain, we shall be at once struck with the difference, not only of species but of genera, which each stage exhibits from the one below or above it; and I can confidently say that, during the whole course of my collecting from these strata, I have invariably found that this order is most exactly, and even extraordinarily, maintained.

No one has yet, I believe, attempted to analyze and divide the Gloucestershire Cephalopoda-bed in this minute fashion. Two divisions at the most were made; but for our present purpose many divisions are necessary; and any one, when he becomes thoroughly acquainted with the different beds and their Ammonite-fauna, will be able to see that these divisions are fairly well characterized. It is, in fact, only by making such particular divisions that we are able

* "Basement-beds of the Inferior Oolites of Gloucestershire," Quart. Journ. Geol. Soc. vol. xlii. p. 264 *et seq.*

to trace the true correlation of the Midford and Yeovil Sands with the various strata in the Cotteswolds.

1st. The Midford Sands are on the same horizon as the *Dispansum*-beds, and perhaps as some of the higher divisions.

2nd. The Yeovil Sands are above the *Dispansum*-beds, are on the horizon of the *Dumortieria*-, the *Moorei*-, and part of the *Opalinum*-beds.

If I have been able to make my remarks clear, it follows that the sands were by no means contemporaneous in the various districts. The same horizon which in the Haresfield-Wotton district is noted for its sand is blue clay at Ilminster. What is sand at Burton Bradstock is an ironshot limestone in Gloucestershire. What are the consequences of this upon our nomenclature? The style of nomenclature in general use at present combines the Cotteswold Sands plus the Cephalopoda-bed, the Midford Sands, and the Yeovil Sands under one name "Midford Sands," and, placing them as the next stage above the Upper Lias, includes them in the Inferior Oolite Series *. As I have shown, however, the Cotteswold Sands and even part of the Cephalopoda-bed, and the Midford Sands so far as we know them, are absolutely contemporaneous with the Upper Lias of Ilminster. The diagram (fig. 1, facing this page) will exhibit this at a glance.

I may note the following facts to support my statement that the *Striatulum*-beds are in the Upper-Lias Clay of Somerset—that the top of this clay is, in fact, on the same horizon as the Cotteswold Sands and part of the Cephalopoda-bed of Gloucestershire.

Charles Moore, who always considered the Yeovil Sands to belong to the Inferior Oolite, has placed the following species in the Bath Museum as from the *Upper Lias* of Ilminster †:—

Hammatoceras insigne (Schubler), *Grammoceras striatulum* (Sow.), *Gramm. fallaciosum*, Bayle, *Gramm.*, sp. (called *radians*) ‡.

Oppel, 'Juraformation,' p. 250, footnote, says "Mr. Moore aus Bath sandte mir den *Amm. variabilis* aus den Umgebungen von Ilminster, mit dem besondern Bemerken, dass die Exemplare aus dem höchsten Bette des obern Lias stammen. Dies ist aber nichts anderes als die zone des *Amm. jurensis*."

With these facts before us how is it possible to treat the "Midford Sands" as of later date than the "Upper Lias," seeing that the greater part of two of their constituents are absolutely contemporaneous therewith?

* H. B. Woodward, 'Geol. England and Wales,' 2nd ed. p. 285 *et seq*.

† It is instructive to notice how Dr. Wright has interpreted this fact concerning the Ilminster strata, and brought it into accordance with Gloucestershire. In Quart. Journ. Geol. Soc. vol. xii. 1856, "Upper Lias Sands," p. 317, he states that in three horizons which he calls, beginning with the lowest, Upper Lias Clay, Upper Lias Sands, and Upper Lias Cephalopoda-bed, the following species of Ammonites have been found—*Amm. insignis*, *Amm. variabilis*, *Amm. radians*, *Amm. Raquinianus*, *Amm. concavus*, *Amm. striatulus*. Practically speaking, the statement is true enough; but they are not three horizons. They are one and the same horizon showing a lithology varying with the locality; this it is that has misled him.

‡ Compare also Moore, Proc. Somerset Arch. Soc. vol. xiii. p. 131 (1865–66).

ive Diagram of the Strata of the Cotteswol
(Scale 50 feet to 1 inch.)

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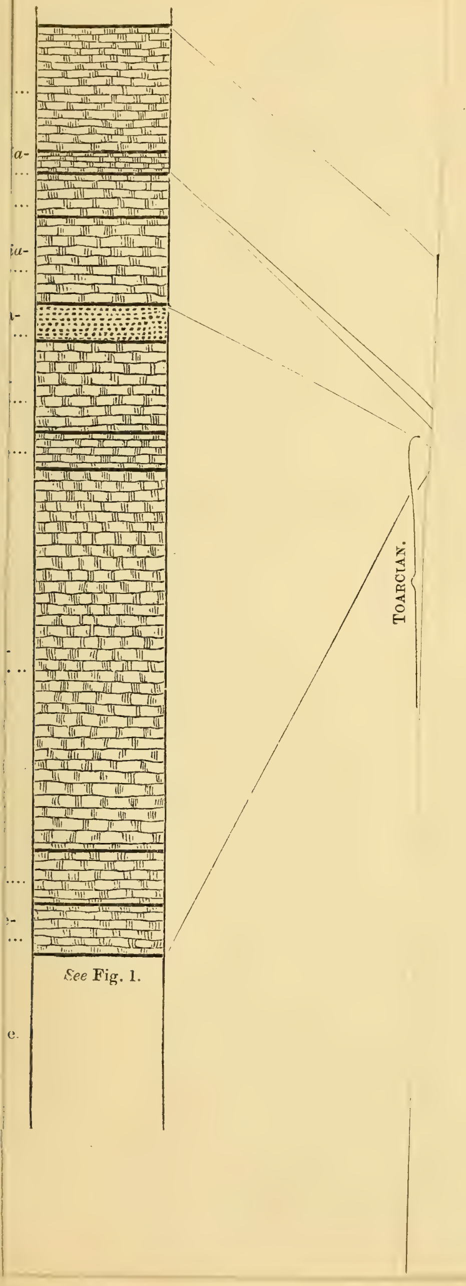


Fig. 1.—*Comparison of the Cotteswold, Midford, and Yeovil Sands.* (Scale 50 feet to 1 inch.)
(Some of the smaller divisions are, of necessity, exaggerated.)

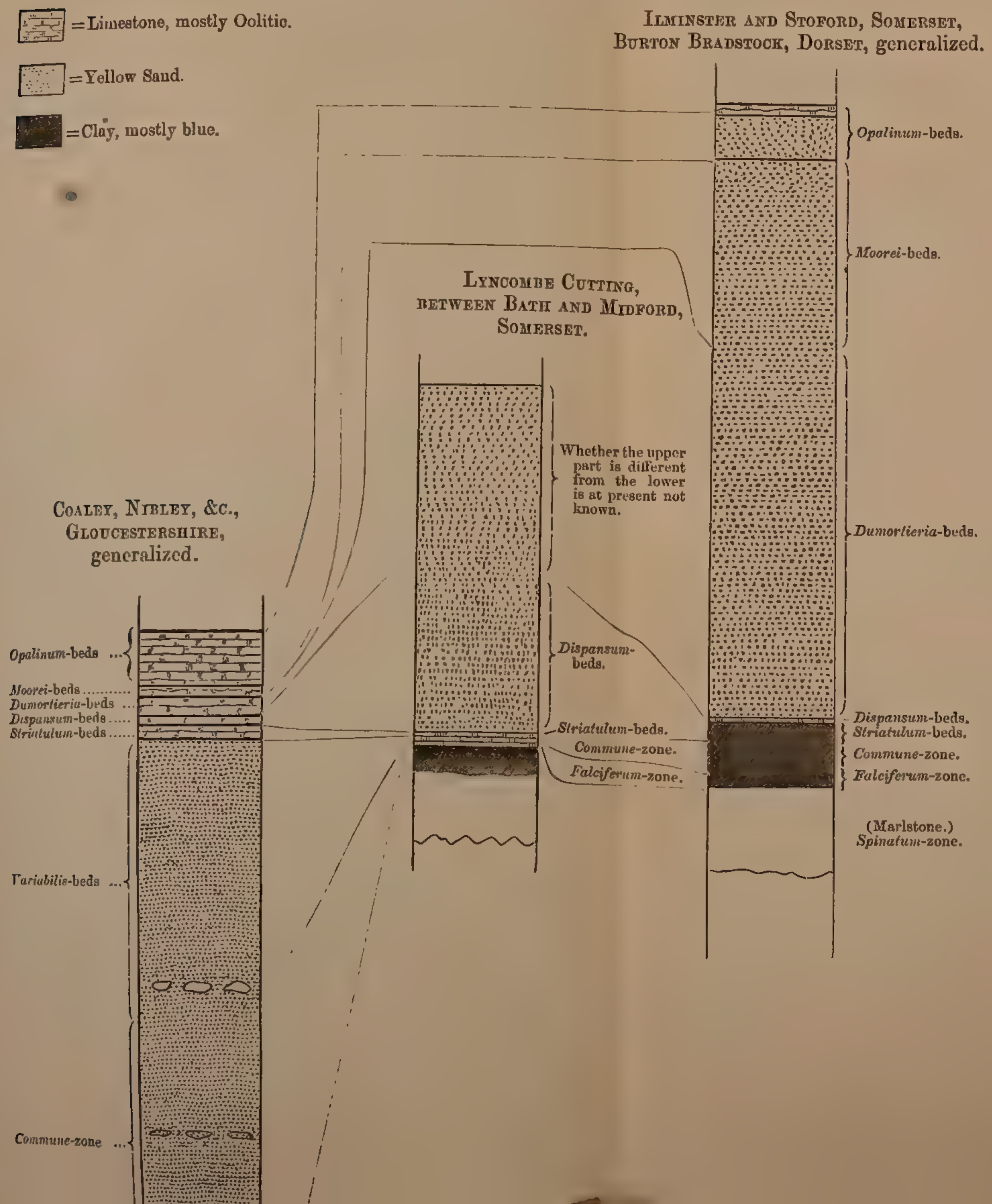
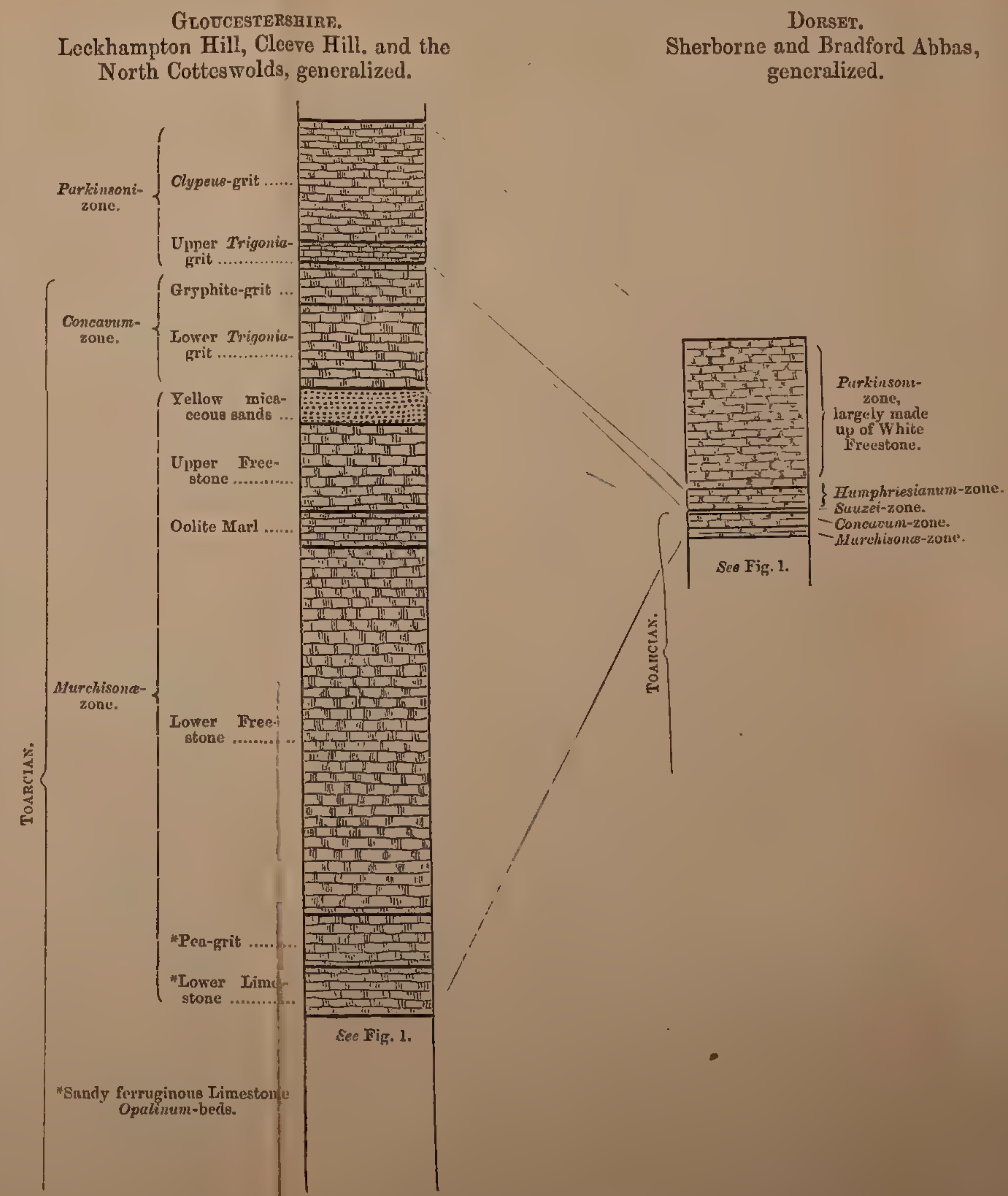


Fig. 2.—*Comparative Diagram of the Strata of the Cotteswolds and the Sherborne District.*
(Scale 50 feet to 1 inch.)



* Formerly all these were combined under the term Pea-grit.

On the other hand the "Midford Sands" have been defined as equal to the zones of *Amm. opalinus* and *Amm. jurensis* *; but, in all probability, the lower part of the Cotteswold Sands—the part containing *Amm. bifrons*—belongs to the *Commune*-zone. Then, too, it is just the opposite in Somerset, where it is the Upper-Lias Clay of Ilminster which contains the greater part of the *Jurense*-zone. Again, part of the Inferior-Oolite Limestone of Dorset and of the Cotteswolds is in the zone of *Amm. opalinus*. Therefore this latter definition does not coincide with the first.

According to either view we arrive at an absurdity, namely, part of the Upper-Lias Clay must be in the Inferior Oolite series; or beds containing several of the same species of Ammonites must be in the Lias in one place, and in the Inferior Oolite in another.

After all, the term "Midford Sands" is only used locally. The Dogger Sands of Yorkshire, and part of the Northampton Sands, are contemporaneous with the upper part of the Yeovil Sands; but they are not included in the term "Midford Sands." Is there the least advantage in retaining a term—a merely local term—which, as I have shown, includes deposits that are, by no means, contemporaneous? Its only advantage is that it does away with two names; but the result is absolute inaccuracy. The terms Cotteswold, Midford, and Yeovil Sands may be retained as merely local names for certain deposits, in the same way as Pea-grit, Oolite Marl, &c.; they should have no wider signification than the district to which they apply, and should not be used where strict scientific accuracy is required, but should give place to their zonal equivalents.

It would almost seem as if the sands between Liassic Clay and Oolitic Limestone were a somewhat singular deposit; but the fact of the matter is, that from a rather remote period until a much later one than we are treating of, sandy strata have been deposited—in no two districts contemporaneously, but generally first in one place and then in another. Why, then, is it desired to mark off the "Midford Sands" as a distinct series—not all across England, but only locally?

The *Jamesoni*- and *Capricornum*- zones are characterized by micaceous and sandy shales at Robin Hood's Bay in Yorkshire †.

The *Henleyi*-zone in Gloucestershire is largely made up of sandy strata very similar to the Cotteswold Sands.

The *Margaritatus*- and *Spinatus*-zones in Dorset contain sandy strata often undistinguishable from the Yeovil Sands.

The zone of *Amm. annulatus* in Yorkshire is represented by hard and compact, grey and micaceous sandy shale ‡.

What is probably the upper part of the *Commune*-zone is composed of micaceous sands in Gloucestershire.

The *Jurense*-zone is made up of sands at Bath, while, lastly, the *Opalinum*-zone at Burton Bradstock is chiefly sands.

Passing to the continent, Oppel § shows us that at Wasseralfingen

* H. B. Woodward, *op. cit.* p. 285.
† H. B. Woodward, *op. cit.* p. 269.
‡ H. B. Woodward, *op. cit.* p. 277.
§ Oppel, 'Juraformation,' p. 328.

the greater part of the *Murchisonæ*-zone consists of "Sandstein;" while, apparently, the Clays and Shales,—considered in England so distinctive of the Lias—continued to a much later period; because the zone of *Trigonia navis* is described as consisting of "Dunkle gegen oben glimmerreiche Thone" *.

Returning to the North Cotteswolds, we find yellow sands at the top of the *Murchisonæ*-zone; while, in the Banbury district, Northampton Sand continues without intermission from the *Opalinum*-zone until the lower part of the Great Oolite inclusive †.

The foregoing remarks will show that, putting different localities together, there exist, with but very few breaks—which breaks continental strata would perhaps bridge over—deposits of sands, sandy marls, or sandstone from the time of the *Jamesoni*-zone to the lower part of the Great Oolite inclusive. Thus the obvious inference is that the presence of sandy lithological conditions is no guide to the age of the deposits; consequently we ought not to be surprised at finding the Cotteswold, Midford, and Yeovil Sands upon three different horizons; the surprise would be to find them on the same horizon.

If we abolish the general name "Midford Sands," and retain the names Cotteswold, Midford, and Yeovil Sands as local names for deposits on three different horizons, what are we to do as regards the dividing line between Lias and Oolite, which has always been such a bone of contention? If we follow the method of Quenstedt, Oppel, and others, and draw the line of division between Oolite and Lias at the top of the *Jurense*-zone, we must draw a very arbitrary line through the middle of the Cephalopoda-bed in Gloucestershire, and through the middle of the Yeovil Sands in the district south of the Mendips. If we follow H. B. Woodward, and place the whole of the sands—and their horizontal equivalents, I suppose—in the Inferior-Oolite series, we must dive down into what is known as Upper Lias Clay in Somerset, to draw a very arbitrary line, and a line, too, totally unacceptable to continental geologists. If we follow Dr. Wright, and draw the line of demarcation above the *Opalinum*-zone, we find that it results in parting a series of thoroughly oolitic limestones from the Inferior Oolite, and it thus becomes an arbitrary line.

All these remarks will only show (1) that between the Lias and the Oolite there practically exists no constant lithological break anywhere in the region where it has usually been sought; (2) that the old idea, that the sands necessarily marked a transition period between the Lias and the Oolite, cannot be held. Such being the case, shall we adopt a perfectly arbitrary line of division irrespective of where it falls? Or is it possible to do without this?

Dr. Vacek ‡ has proposed to extend the Lias up to the top of the *Murchisonæ*-zone; and, in the correspondence that we have had upon the subject, he would extend it to the top of our *Concavum*-

* Oppel, 'Juraformation,' p. 321. † Woodward, *op. cit.* p. 310.

‡ "Die Fauna der Oolithe von Cap San Vigilio," Abh. der k.-k. geologischen Reichsanstalt, Bd. xii. no. 3.

beds. To anyone acquainted with the Cotteswolds the idea of placing the greater part of the thoroughly oolitic strata there exhibited—the Pea-grit, Lower Freestone, Oolite Marl, Upper Freestone, Lower Trigonia-grit, and Gryphite-grit—in the Lias must seem very extraordinary; but anyone who visits Dundry in North Somerset, Corton Downs in South Somerset, and Sherborne in Dorset, and sees the *Concavum*-beds of those places, with their truly Liassic appearance, and remembers at the same time that clayey conditions prevailed on the continent until a much later date than with us, will begin to understand the motives which sway continental geologists when they wish to place these strata in the Lias *.

I was strongly opposed to Dr. Vacek's views at first, especially because he had made many errors in describing our English strata; and had then drawn inferences therefrom which I knew could not be sustained.

Now, instead of regarding them as Lias, I propose (being especially struck with certain palæontological features of the series) to describe all the strata from the *Falciferum*-zone to the top of the *Concavum*-beds by d'Orbigny's term "Toarcien"; but I would not place the strata so named as subsidiary to either Lias or Oolite. I cannot say that this idea is new. Prof. Eugène Deslongschamps (*op. cit.* footnote, p. 100) says of the same series: "Les marnes infrà-oolithiques représentent exactement l'étage Toarcien de M. d'Orbigny." Now he had already proposed the following classification for a portion of the Jurassic strata (pages 70, 71):—

"SYSTÈME OOLITHIQUE INFÉRIEUR.
1°. Les marnes infrà-oolithiques;
2°. L'oolithe inférieure;
3°. Le fuller's earth;
4°. La grande oolithe."

The first and lowest of these stages, namely, "*Les marnes infrà-oolithiques*," are stated to be composed as follows (pp. 73, 74):—

1°. Argiles à poissons.	
2°. Marnes moyennes.	1°. Couches à *Ammonites bifrons* et *serpentinus*; 2°. Id. à *Ammonites* et *Lima toarcensis*.
3°. Calcaires supérieures à *Ammonites Murchisonæ*.	1°. Couches à *Ammonites primordialis*; 2°. Id. à *Terebratula perovalis*.

From this we see that d'Orbigny's "Toarcien" and Prof. Eugène Deslongschamps's "Marnes infrà-oolithiques" comprise what we now know as Upper Lias, together with what Mr. Hudleston calls the Lower division of the Inferior Oolite, namely, to the top of the zone of *Lioceras concavum* †.

* D'Orbigny placed these same beds in the Lias—Toarcien = Upper Lias. Eugène Deslongschamps was at first of the same opinion (Etudes jurass. inf. Normandie, p. 99, footnote, 1864).

† This horizon was formerly called the "*Sowerbyi*-zone." The reason for the present designation may be found in Mr. Hudleston's Monogr. Gast. Inf. Oolite, p. 44, Pal. Soc. (March 1887), and in my Monogr. Inf. Ool. Amm., Pal. Soc. p. 63, March (1889).

As soon as I clearly grasped the facts concerning the so-called "Midford Sands," and when I became aware of certain palæontological evidence which I shall have to mention presently, it occurred to me to propose that the "Toarcien" should be a separate and distinct division of the Jura-formation, or, if it be preferred, a distinct formation of the Jurassic system. I now find, however, that in this matter I have long ago been forestalled. Eugène Deslongschamps says his father considered the series I propose to call "*Toarçien*" as an intermediate subformation of very distinct character *, and I am inclined to agree with this opinion, rather than include these strata in the Inferior-Oolite series; because there exists a far more marked stratigraphical and palæontological break at the end of the "Toarcien" than at the beginning. Consequently, in my opinion, those who would relegate the "Toarcien" to the Lias have the weight of evidence upon their side; but I am opposed to this view, because to us, in England, it seems so entirely misleading and anomalous to call the *Murchisonæ*- and *Concavum*-zones—in the Cotteswolds nearly the whole Oolitic escarpment—by the term Lias. Again, there is quite a sufficient palæontological break at the beginning of the "Toarcien" to warrant our making it a distinct stage or formation; and probably stratigraphical evidence will also justify this proceeding. The term "Toarcien" commits us to nothing like the term "Inferior Oolite;" it does not say whether the strata are clay, sand, or limestone; and considering how unreliable a guide lithology is, I consider this a very important point. Those who are apt to defend the present divisions, especially Inferior Oolite, 1st, because of the Oolitic character of its rocks, composed, too, of a limestone, in distinction to the clay or sand below, 2nd, because this mass of limestone forms such an important and well-marked—easily recognizable—feature in the country, should remember that this is by no means always the case, even in England; while over the much greater area—the Continent—it is the exception; because clay, sand, or marl are wont to make up a large part of the *Murchisonæ*-zone and of the zones below it.

The term "Toarcien" will supersede a number of names which have been applied to its various constituents, namely, Upper Lias Clay, Upper Lias Sands, Supra-liassic Sands, Inferior-Oolite Sands, Midford Sands, Infra-oolitic marls, Lower division of the Inferior Oolite, Lower Bajocien, &c.

Prof. Deslongschamps (*op. cit.* p. 100, footnote) says that the name "Toarcien" was unfortunately chosen, because at Thouars many of the beds of this age are wanting; in Normandy the series is more complete, but thin and irregular; but in the Moselle department the strata are most complete.

In order to show this, he appends a Table of the strata in the different localities (p. 101), part of which I here reproduce (Table I., facing this page); but as the strata of Dorset are certainly more developed and show fewer lacunæ than even those of the Moselle, I place them, and also those of the Cotteswolds, side by side with

* See Eugène Deslongschamps, *op. cit.* p. 98.

[*To face* p. 460.

TABLE I.

Correlation of certain Jurassic beds in the following localities.

	Normandy.	Thouars (carrière de Verrines).	Moselle.	Dorset and South Somerset.	Cotteswolds.
Oolithe inférieure.	Oolithe ferrugineuse de Bayeux.	Manque.	Partie du minerai de Longwy.	Hard, ironshot Oolite with *Amm. Humphriesianus.* Grey marl, with green grains, with *Amm. Sauzei.*	Absent.
				Ironshot Oolite limestone, with *Amm. concavus, discites, discoideus,* &c., *Terebr. perovalis.*	The Gryphite grit, with *Amm. discites, discoides,* &c. The Lower Trigonia-grit.
	Malière des géologues Normands.		Minerai de fer de Longwy et des environs de Nancy ovoïdes ferrugineux.	Ironshot Oolite limestone, with *Amm. Murchisonæ* *natus.*	The Upper Freestone. The Oolite Marl. The Lower Freestone. *natus* and *margaritatus.*

TABLE I.

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Marnes infrà-oolithiques.				Ironshot Oolite limestone, with *Amm. concavus, discites, discoideus,* &c., *Terebr. perovalis.*	The Gryphite grit, with *Amm. discites, discoides,* &c. The Lower Trigonia-grit.
	Matière des géologues Normands. Calcaire marneux avec chlorite et silex branchus. *Ter. perovalis.*	Manque.	Minerai de fer de Longwy et des environs de Nancy avec *Amm. Murchisonæ.*	Ironshot Oolite limestone, with *Amm. Murchisonæ* and *ambiguus. Terebr. perovalis.*	The Upper Freestone. The Oolite Marl. The Lower Freestone. The Pea-grit, with *Amm. Murchisonæ.* The Lower Limestone.
	Oolithe ferrugineuse à *Ammonites primordialis* et *Astarte excavata.*	Calcaire marneux blanchâtre avec silex et *Rhynchonella cynocephala.*	Marnes micacées. Minerai de fer avec *Amm. primordialis.*	Grey Oolite limestone with *Amm. opalinus* (*primordialis*).	The sandy ferruginous limestone, with *Amm. opalinus.*
	Manque.	Manque.	Marnes supérieures de Gundershoffen à *Amm. primordialis* et *Trigonia navis.*	Yellow micaceous sands with *Amm. opalinus* and *torulosus.*	Ironshot Oolite, with *Amm. opalinus* and *Moorei.*
	Manque.	Manque.	Marnes inférieures de Gundershoffen avec *Amm. torulosus.*		Ironshot Oolite, with *Amm. torulosus.*
	Calcaire et argiles bleues avec *Belemnites irregularis, Amm.* et *Lima toarcensis.*	Calcaires et argiles grises avec *Belemnites irregularis, Amm.* et *Lima toarcensis.*		Blue clay and limestone, with *Amm. insignis, Amm. striatulus* (*toarcensis*), *Amm. fallaciosus* (*radians*).	Ironshot Oolite with *Amm. insignis, Amm. striatulus* (*toarcensis*). Yellow sands, with *Amm. variabilis.*
	Niveau des Gastéropodes, *Trochus subduplicatus.*	Niveau des Gastéropodes.	Marnes avec *Ammonites radians* et *bifrons.*	Clay and stone, with *Amm. bifrons, Amm. falcifer* (*serpentinus*).	Yellow micaceous sands with *Amm. bifrons.* Blue clay and limestone, with *Amm. bifrons* and *Amm. falcifer* (*serpentinus*).
	Marnes et argiles avec *Ammonites bifrons* et *serpentinus.*	Calcaire à *Ammonites bifrons* (banc lumateux). Argile feuilletée avec *Amm. serpentinus.*			
	Argile. □ □ Calcaire à *Amm. jurensis.* Argile. □ Calcaire en nodules aplatis avec poissons et autres vertébrés. Argile.	Manque.	Marnes. Calcaire gréseux à poissons et *Teleosaurus temporalis.* Calcaire noduleux à poissons. Marnes bitumineuses.	The Saurian and Fish zone (Moore).	The Saurian and Fish-bed (Moore).
Lias à Bélemnites.	Couche à Leptæna.	Manque.	Grès médioliassique? (Terquem).	The Leptæna beds (Moore).	The Leptæna beds (Moore).
	Couche à *Ammonites margaritatus* et *spinatus.*	Calcaire et poudingue à *Pecten æquivalvis.*	Lias à Belemnites avec ovoïdes ferrugineux.	Marlstone, with *Amm. spinatus.*	Marlstone, with *Amm. spinatus* and *margaritatus.*

the French localities for comparison. The only observation which I have to make upon this Table is that in the first column the "Calcaire à *Amm. jurensis*," placed below the *Bifrons*- and *Serpentinus*-beds, is totally at variance with all present knowledge, and is probably an error.

The great variation in the lithology of the different localities upon the same horizon should be noticed.

I will now proceed to consider the evidence in favour of the proposed Toarcian division and will in consequence begin with the palæontological aspects of the case.

The family Hildoceratidæ dominate this period. They appear suddenly with the *Falciferum*-zone, and die out abruptly with the exit of the *Concavum*-beds. Prior to the former, or subsequent to the latter, only a very few species are found. The annexed Table of the range of the species and genera of the family Hildoceratidæ will fully bear out these remarks.

TABLE II.†

	Jamesoni-zone.	*Ibex*-zone.	*Henleyi*-zone.	*Margaritatus*-zone.	*Spinatum*-zone.	*Falciferum*-zone.	*Commune*-zone.	*Jurense*-zone.	*Opalinum*-zone.	*Murchisonæ*-zone.	*Concavum*-zone.	*Sauzei*-zone.	*Humphriesianum*-zone.	*Parkinsoni*-zone.
Family HILDOCERATIDÆ.														
Hildoceras														
bifrons (*Brug.*)	...	...	...	...	...	...	*	*	*					
Levisoni (*Simps.*)	...	...	...	...	...	*	*							
Frantzi (*Reynès*)	...	...	...	...	...	...	...	*						
Douvillei (*Haug*)	...	...	...	...	...	*								
Kiliani, *Haug*	...	...	...	...	...	*								
boreale (*Seebach*)	...	...	...	...	...	...	*							
serpentinum (*Reinecke*)	...	...	...	...	...	*								
Lillia														
comensis (*Buch*)	...	...	...	...	...	...	*							
tirolensis (*Hauer*)	...	...	...	*										
Lilli (*Hauer*)	...	...	...	...	...	...	*							
erbaensis (*Hauer*)	...	...	...	...	...	...	*							

† For information concerning the position of many of these species (especially those of older authors), I must acknowledge myself indebted to Dr. Haug's memoir on *Harpoceras*: Neues Jahrbuch für Mineralogie &c. Beil. Bd. iii. 1885.

Many of Dumortier's species are given by him as from the zone of *Amm. bifrons* (=*Commune*- and *Jurense*-zones above). In such cases I have referred the species to the *Commune*-zone, unless I had knowledge or evidence to the contrary.

The zone of *Amm. Parkinsoni* does not, to my knowledge, contain any species belonging to this family; but certain members thereof (descendants of the genus *Ludwigia*) occur in the strata above. Other species in the same horizon perhaps belong to this family; but at present we are only concerned with those in the zones here given.

TABLE II. (*continued*).

	Jamesoni-zone.	*Ibex*-zone.	*Henleyi*-zone.	*Margaritatus*-zone.	*Spinatum*-zone.	*Falciferum*-zone.	*Commune*-zone.	*Jurense*-zone.	*Opalinum*-zone.	*Murchisonæ*-zone.	*Concavum*-zone.	*Sauzei*-zone.	*Humphriesianum*-zone.	*Parkinsoni*-zone.
Lillia (*cont.*)														
rheumatisans (*Dumort.*)							*							
Escheri (*Hauer*)							*							
robusta (*Denckmann*)								*						
Bayani (*Dumortier*)							*							
sulcata, *Buckman*													*	
Pœcilomorphus														
Mercati (*Hauer*)							*							
macer, *Buckman*												*		
cycloides (*d'Orbigny*)													*	
Ludwigia														
Murchisonæ (*Sowerby*)										*				
Lucyi, *Buckman*											*			
costosa (*Quenstedt*)									*					
cornu, *Buckman*											*			
rudis, *Buckm.*											*			
Lioceras														
elegans (*Young & Bird*)						*								
opalinum (*Reinecke*)									*					
concavum (*Sowerb.*)											*			
fallax, *Buckm.*											*			
apertum, *Buckm.*											*			
bradfordense, *Buckm.*										*	*			
decipiens, *Buckm.*											*			
ambiguum, *Buckm.*										*				
Pseudolioceras														
lythense (*Young & Bird*)						*	*							
compactile (*Simpson*)							*	*						
lympharum (*Dumort.*)							*							
Beyrichi (*Schlönb.*)									*					
simile (*Simpson*)						*								
Hyperlioceras														
discites (*Waagen*)											*			
discoideum (*Quenstedt*)											*			
subdiscoideum, *Buckm.*											*			
Desori (*Mœsch.*)											*			
Walkeri, *Buckm.*											*			
Harpoceras														
falciferum (*Sow.*)						*								
exaratum (*Young & Bird*)						*								
subplanatum (*Oppel*)								*						
bicarinatum (*Zieten*)							*							
elegans (*Sowerby*)							*							
Strangewaysi (*Sowerby*)						*								
crassifalcatum (*Dumort.*)									*					
connectens (*Haug*)							*							
Harpoceras?														
Curioni, *Meneghini*				*										
boscense (*Zittel*)				*										

TABLE II. (*continued*).

	Jamesoni-zone.	*Ibex*-zone.	*Henleyi*-zone.	*Margaritatus*-zone.	*Spinatum*-zone.	*Falciferum*-zone.	*Commune*-zone.	*Jurense*-zone.	*Opalinum*-zone.	*Murchisonæ*-zone.	*Concavum*-zone.	*Sauzei*-zone.	*Humphriesianum*-zone.	*Parkinsoni*-zone.
Harpoceras ? (*cont.*)														
pectinatum, *Meneghini*	...	...	...	*										
subconcavum, *Blake*	...	...	...	...	...	...	*							
Hildoceras ?														
algovianum (*Oppel*)	...	...	...	*										
retrorsicosta (*Oppel*)	...	...	...	*										
nitescens (*Young & Bird*)	...	...	...	*										
Grammoceras														
antiquum (*Wright*)	*													
Normanianum (*d'Orb.*)	...	...	...	*										
radians (*d'Orbigny*)	...	...	...	...	...	...	...	*						
striatulum (*Sowerby*)	...	...	...	...	...	...	...	*						
acutum (*Tate*)	...	...	...	...	*									
pseudoradians (*Reynès*)	...	...	...	*										
Kurrianum (*Oppel*)	...	...	...	*										
fallaciosum, *Bayle*	...	...	...	...	...	...	...	*						
Bingmanni (*Denckmann*)	...	...	...	...	...	...	...	*						
Struckmanni (*Denckm.*)	...	...	...	...	...	...	...	*						
Sæmanni (*Oppel*)	...	...	...	...	...	...	...	*						
Muelleri (*Denckm.*)	...	...	...	...	...	...	...	*						
capillatum (*Denckm.*)	...	...	...	..	...	...	*							
Ruthenense (*Reynès*)	...	...	...	*										
Bodei (*Denckm.*)	...	...	...	...	...	...	...	*						
quadratum (*Haug*)	...	..	...	...	...	...	...	*						
Cæcilia (*Reinecke*), (*Blake*)	...	...	...	...	...	*								
dœrntense (*Denckm.*)	...	...	...	...	...	...	...	*						
Emilianum (*Reynès*)	...	...	...	...	...	...	*							
dispansum (*Lycett*)	...	...	...	...	...	...	...	*						
latescens (*Simpson*)	...	...	...	...	...	*								
subcomptum (*Branco*)	...	...	...	...	...	...	...	...	*					
mactra (*Dum.*)	...	...	...	...	...	...	...	...	*					
costula (*Reinecke*)	...	...	...	...	...	...	...	...	*					
fluitans (*Dumortier*)	...	...	...	...	...	...	...	...	*					
aalense (*Zieten*)	...	...	...	...	...	...	...	...	*					
lotharingicum (*Branco*)	...	...	...	...	...	...	...	...	*					
Steinmanni (*Haug*)	...	..	..	...	...	...	...	...	*					
metallarium (*Dumortier*)	...	...	...	...	...	...	...	*						
Gruneri (*Dumortier*)	...	...	...	...	...	...	*							
ovatum (*Young & Bird*)	...	...	...	...	...	...	*							
sp.	...	...	...	...	...	...	...	...	...	*				
Haugia														
variabilis (*d'Orbigny*)	...	...	...	...	...	...	...	*						
navis (*Dumort.*)	...	...	...	...	...	...	...	*						
malagma (*Dumort.*)	...	...	...	...	...	...	...	*						
Ogerieni (*Dumort.*)	...	...	...	...	...	...	...	*						
illustris (*Denckm.*)	...	...	...	...	...	...	...	*						
Eseri (*Oppel*)	...	...	...	...	...	...	...	*						
occidentalis (*Haug*)	...	...	...	...	...	...	...	*						

I have tabulated herein 96 species of this family, and I believe that, with very few exceptions which I have not had opportunity to study, these include all the Ammonites which belong to this family in the zones mentioned. It will be noticed that, of all these species, only three survive the period known as the *Concavum*-beds, a fact which cannot but be regarded as extremely striking; while, on the other hand, only 13 of the species appeared prior to what I propose to name Toarcian. Thus we are left with 80 species of this one family as existing during the Toarcian period; and we may, I think, with propriety, define this period as the one which was dominated by the family Hildoceratidæ. Curiously enough, different portions of the Toarcian were dominated by certain genera of this family: thus *Hildoceras*, *Harpoceras*, and *Lillia* dominate the *Falciferum*- and *Commune*-zones; *Grammoceras* dominates the *Jurense*- and *Opalinum*-zones; *Ludwigia*, *Lioceras*, and *Hyperlioceras* dominate the *Murchisonæ*- and the *Concavum*-zones.

It would seem that the upper limit of the Toarcian is more sharply defined upon the continent than with us, owing to the absence, apparently, of the *Concavum*-beds from the continent. I fancy that the *Concavum*-zone helps to bridge over the hiatus between the *Murchisonæ*- and so-called *Sowerbyi*-zones of the continent, and therefore it gives a certain amount of difficulty. It is quite true that the Hildoceratidæ come to a sudden end within the *Concavum*-zone, as the Table shows; but we also meet with a number of species (as yet undescribed) of the genus *Sonninia*; and this genus is one which belongs especially to the strata above the *Concavum*-zone, and therefore helps to connect it therewith. It was the presence of these *Sonniniæ* (some of which are very similar to, though precursors of, *Sonninia Sowerbyi*) which caused me to call the *Concavum*-zone "the *Sowerbyi*-zone"; especially as they make a sudden and quite unexpected appearance in the *Concavum*-zone and are absent from the *Murchisonæ*-zone. Probably we must not expect to find any division where there is not some connexion with strata above; and the value of these *Sonniniæ* is again balanced by *Hammatoceras*, a genus which began in the *Jurense*-zone and ended, apparently rather abruptly, in the *Concavum*-zone, having been fairly persistent through the intermediate strata. The presence of members of the genera *Oppelia* and *Lissoceras* is evidence neither one way nor the other; it connects the strata no more with the *Oppeliæ* of the *Opalinum*-zone than with those of the *Humphriesianum*-zone. The presence of one or two small species of *Stephanoceras* perhaps tends rather to unite the *Concavum*-zone with the strata above them. But the presence of *Lytoceras confusum* (a member of the *Jurense*-group) unites the *Concavum*-zone very forcibly with the rest of the Toarcian by means of the following series:—*Lytoceras jurense*, in the zone of that name; *Lytoceras Wrighti*, in the *Opalinum*-zone; *Lytoc. amplum* in the *Murchisonæ*-zone; because we must remember that *Lytoceras Eudesianum* of the *Humphriesianum*-zone does not belong to the *Jurense*-group of the *Lytocerata*, but to the *Fimbriatum*-group. After all, the strongest palæontological

evidence in favour of a break above the *Concavum*-zone is that thirteen species of Hildoceratidæ occur in the *Concavum*-zone, while only one is found in the succeeding *Sauzei*-zone.

The geological evidence in favour of a break above the *Concavum*-zone is somewhat striking. The failure of the *Humphriesianum*- and *Sauzei*-zones in the majority of English localities affords us at once a very definite break, and leaves us with few, if any, places where there would be anything like drawing a really arbitrary line. At Dundry the *Humphriesianum*- and *Sauzei*-zones are present; at Milborne Wick and in the neighbourhood of Sherborne the same holds good; these are the places where we may expect opposition. At Burton Bradstock and in the Bridport neighbourhood the *Humphriesianum*-zone is feebly represented; but there is a hiatus, due to the absence of the *Sauzei*-zone and the *Concavum*-beds. At Halfway House and Bradford Abbas the *Humphriesianum*-zone is represented by a very thin band, of itself more like a dividing-line than anything else; while the *Sauzei*-zone is probably almost, if not entirely, absent. At Stoford, East Coker, Haselbury, Crewkerne, Broad Windsor, and around Beaminster the *Humphriesianum*-zone is entirely absent—the *Parkinsoni*-zone rests upon the *Murchisonæ*-zone or the *Concavum*-zone. Further north we find, at Cole, the *Parkinsoni*-zone resting on the *Sauzei*-zone, and this, again, on the *Murchisonæ*-zone—the *Concavum*-beds are absent; while at all other places, Castle Cary, Doulting, Cranmore, along the sides of the Mendips, at Radstock, at Midford, and at Bath the *Parkinsoni*-zone rests on sands and, in some instances, on Carboniferous Limestone. Throughout the whole of the Cotteswolds the *Humphriesianum*-zone is absent *; the *Parkinsoni*-zone (Upper Trigonia-grit) rests upon the *Concavum*-zone (Gryphite-grit), but in many parts there is a greater hiatus † than this. From Little Sodbury nearly to Stroud the Upper Trigonia-grit rests upon the Freestone or Limestone of the *Murchisonæ*-zone, and there is a lithologically marked hiatus. In the eastern extension of the Cotteswolds, namely, at Little Rissington, near Stow-on-the-Wold, the *Clypeus*-grit (*Parkinsoni*-zone) rests upon the Upper-Lias Clay, so that the hiatus is now very great.

* I would expressly note, in passing, that I am pleased to think my views upon the proper position of the Gryphite-grit &c. were published before anything of this kind had been thought of, at any rate by me (Proc. Cotteswold Club, vol. ix. 1887), so that it cannot be said that such views were manufactured to meet the exigencies of the situation. It can, however, be seen how extremely important such views have become in connexion with the present ideas. The zonal arrangements of the Cotteswolds, according to Dr. Wright and Prof. Judd, whereby the Upper Freestone &c. represented the *Humphriesianum*-zone, and the Oolite Marl the *Sowerbyi*-zone, would have greatly interfered with the working-out of the present views.

† In the North Cotteswolds this hiatus is marked lithologically by a bored bed covered with oysters. In the South Cotteswolds the junction of the Upper Trigonia-grit and the Gryphite-grit is not so distinguished; but this is paralleled by Castle Cary (p. 447). At the same time there is, singularly enough, a distinct lithologically-marked hiatus in this district, on a lower horizon, namely at the top of the Upper Freestone; but this hiatus means the absence of the Lower Trigonia-grit of the Cheltenham district, some 24 feet of strata.

So far I can speak almost entirely from my own knowledge of the various localities. To continue the subject:—Dr. Wright * notices that near Burford, and in the north-eastern parts of the Northleach district of the Cotteswolds, the *Parkinsoni*-zone rests upon the Upper Lias. Mr. Hudleston † says that further eastwards, namely, at Hook Norton, in Oxfordshire, the *Parkinsoni*-zone rests on the *Murchisonæ*-zone and that there is therefore a hiatus.

In a section of the Northampton district, very kindly sent to me by Mr. Thompson, an "Unconformity" is said to exist between the Lower Estuarine series (Northampton Sand, *Murchisonæ*- or *Opalinum*-zone?) and the Upper Estuarine series (Great Oolite).

At Rockingham, Stamford, and Grantham Prof. Judd ‡ depicts the Upper Estuarine series (Great Oolite) resting upon the Lincolnshire Limestone of the Inferior Oolite. In Middle and North Lincolnshire he shows the Great-Oolite Limestone resting on the Lincolnshire Limestone. Now he places the Lincolnshire Limestone in the *Sowerbyi*-zone, but at the same time on the level of the "Oolite-Marl" (page 8). In the latter case, the Lincolnshire Limestone would be in the *Murchisonæ*-zone, according to my views, and this is Mr. Hudleston's opinion of its proper position (*op. cit.* p. 72). Therefore we have the same hiatus at the top of the *Murchisonæ*-zone, only that it is now much greater, owing to the absence of all the upper beds of the Inferior Oolite.

In the Yorkshire basin we have the *Humphriesianum*-zone (Scarborough Limestone) resting upon the *Murchisonæ*-zone (Hudleston, *op. cit.* page 75), so that here, too, we have a palæontological hiatus (the *Sauzei*-zone and the *Concavum*-beds being absent), though there is no mention of any lithological one.

I have therefore shown that over nearly the whole of the English Inferior-Oolite area, and especially where the zones can best be distinguished, there already exists a well-marked, ready-made line of division, due to the absence, generally, of the *Humphriesianum*-zone, but very often to the absence of other zones also. In some cases this hiatus is marked stratigraphically by the presence of a bored bed, by the under rock being pitted or covered with oysters, and by other signs of a cessation of deposition; but in other cases a long interval may not be marked in this way, and the two periods may be actually cemented together into one stone (see page 447), so that we again find lithological features to be unreliable.

Dr. Vacek, who has worked this matter out very extensively in connexion with his proposal to include the *Murchisonæ*-zone in the Lias, finds, upon the continent, a very extensive hiatus between the *Murchisonæ*- and so-called *Sowerbyi*-zones. Possibly this *Sowerbyi*-zone, in its strict sense, is more correctly on the horizon of our *Sauzei*-zone; and in that case it seems to me that our *Concavum*-zone is possibly the stratum the absence of which the hiatus represents.

Eugène Deslongschamps (*op. cit.* p. 94) shows that this hiatus,

* "Subdivisions of the Inferior Oolite," Quart. Journ. Geol. Soc. vol. xvi. p. 18 (1860).

† "Gasteropoda of the Inferior Oolite," Palæont. Soc. 1887, p. 71.

‡ Memoirs of Geological Survey, "Geology of Rutland," plate i. (vertical sections).

accompanied by conglomerate and signs of erosion, is also very clearly marked in Normandy as indicated in his figure (No. 19) p. 95. In this is shown also the partial extent of the *Humphriesianum*-zone (the dotted stratum). Its absence at Falaise brings the *Parkinsoni*-zone in contact with the *Malière,* which is what we so frequently find in this country. In fact, if we omit from the above-mentioned diagram the conglomerate and the signs of erosion, if we substitute *Concavum*-beds for *Malière*, Sherborne for Bayeux, and Bradford Abbas for Falaise, and imagine Louse Hill situated a short distance from the latter place, we have exactly the position of the Inferior-Oolite strata in Dorset, as well as their extent and sequence. It may be remarked, however, that in Dorset the absence of any particular beds is not necessarily attended with signs of erosion. Lithologically there may be little to indicate the absence of even a considerable series (page 447).

How the matter stands lithologically for the commencement of the Toarcian I cannot say, because I have not studied the Liassic strata with that minute analysis necessary to grapple with such a task; but in the South-Western counties I know we have a marked lithological change from the hard Marlstone of the Middle Lias to the clays of the *Falciferum*-zone; and this line corresponds with a line of division at present in use. In passing I would note that in drawing dividing-lines we must have regard to what will suit Continental strata as well as our own; that whatever lines we adopt will certainly be bridged over more or less in some places; and that all that we can hope is to choose, as the limits of our divisions, lines which can be drawn with the most ease over the greatest extent of country. Such I claim for the Toarcian.

The following is a general description of the strata for which the term "Toarcian" is proposed.

A variable series of clay, sand, and limestone, during the formation of which the Ammonite-family Hildoceratidæ was dominant, and which series, practically speaking, corresponds in its duration with the beginning and ending of the majority of members of that family.

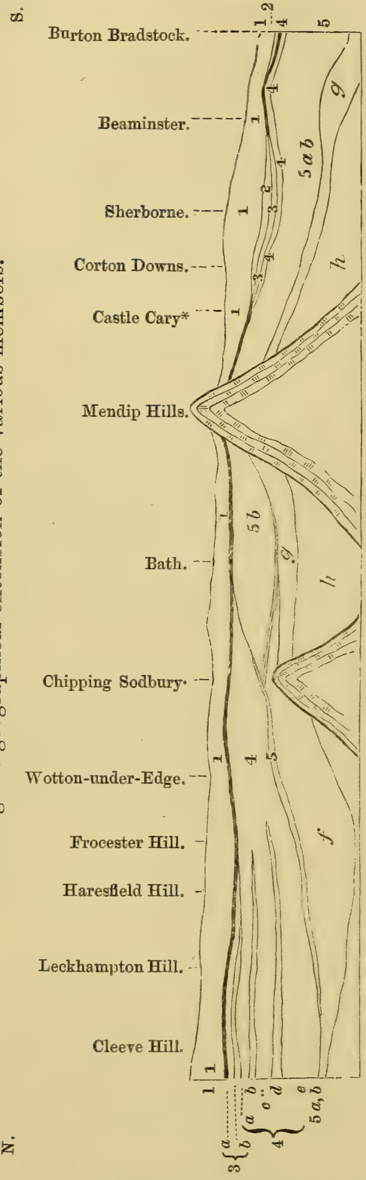
The series comprises the period from the *Falciferum*-zone to the *Concavum*-zone inclusive.

In England the series usually consists of clay at the base, yellow sands in the middle, and oolitic limestone at the top; but the sands may be absent; while clayey or marly conditions may be partially reproduced at the very top (Dundry, Corton Downs).

In the south-western parts of the Jurassic development (counties of Gloucester, Somerset, and Dorset) the duration of the clay is very variable. It may cease, giving place to sands, before the end of the *Commune*-zone, or may last into the middle of the *Jurense*-zone before it gives way. The period of sand-deposit is very variable; it may exist from the middle of the *Commune*-zone to the middle of the *Jurense*-zone, or from the middle of the latter zone to the middle of the *Opalinum*-zone. The oolitic limestone, too, may begin in the middle of the *Jurense*-zone, or may not begin till nearly the end of the *Opalinum*-zone. Argillaceous marl mixed with some limestone may reappear in the *Murchisonæ*- and *Concavum*-zones.

Table III., p. 469, compiled from my own observations, will show the variations in lithology in the different zones, and will

Fig. 3.—*Sketch of the Inferior-Oolite and Liassic Strata,* showing the geographical extension of the various members.



1. *Parkinsoni*-zone.
2. *Humphriesianum*-zone.
3. *Concavum*-zone { *a.* Gryphite-grit. *b.* Lower *Trigonia*-Grit.
4. *Murchisonæ*-zone { *a.* Upper Freestone. *b.* Oolite marl. *c.* Lower Freestone. *d.* Pea-grit. *e.* Lower Limestone.
5. { *a.* *Opalinum*-zone. *b.* *Jurense*-zone, part.

f. The Cotteswold Sands.
g. Argillaceous *Falciferum*-zone.
h. Middle and Lower Lias.

Total distance, ninety miles.
Horizontal scale, sixteen miles to one inch.
Vertical scale much exaggerated, especially the minor divisions.
The thick line represents the persistent hiatus.

* Owing to an unfortunate oversight, sufficient distance has not been allowed between the Mendips and Castle Cary.

demonstrate how impossible it is, from a palæontological point of view, to class all "the sands" as a certain particular series.

TABLE III.*

	CHELTENHAM.	COALEY WOOD.	SODBURY.	BATH.	DUNDRY.	ILMINSTER.	HAM HILL.	CORTON DOWNS.	STOKE KNAP.	BURTON BRADSTOCK AND DOWN CLIFF.
Concavum-zone† ...	Oolitic grits (limestone). Micaceous yellow sands.	Absent.	Absent.	Absent.	Slate-coloured marl and limestone.	Denuded.	Denuded.	Bluish clay and limestone.	Ironshot limestone.	Absent.
Murchisonæ-zone	Freestone (limestone). Marl. Freestone (limestone). Pisolitic limestone. Oolitic limestone.	Freestone (limestone).	Freestone (limestone).	Absent.	Bluish-grey stone.	Denuded.	Denuded.	Yellow limestone.	Pale yellow limestone.	Thin band of limestone.
Opalinum-zone......	Sandy limestone. Ironshot limestone.	Sandy limestone. Ironshot limestone. Hard, ironshot marl.	Sandy limestone. Ironshot limestone. Ironshot marl.	Absent.	Hard bluish-grey shale.	Denuded.	Yellow sands. Freestone. (Yellow shelly sandstone).	Part absent? Yellow sands.	Sandy grits and sands.	Grey limestone. Yellow sands.
Jurense-zone ...	Absent.	Ironshot marl and limestone. Yellow micaceous sands.	Ironshot marl. Yellow sands and sandstone.	Yellow sands. Oolitic limestone.	Bluish-grey sands.	Yellow sands. Brown marl (thin). Yellowish-grey stone (thin). Blue clay.	Probably as at Ilminster.	×	×	Yellow sands. Blue clay.
Commune-zone ...	Blue and yellow sands. Blue clay.	Yellow and blue micaceous sands. Blue clay.	×	Oolitic limestone (thin band).	Blue clay?	Bluish-grey clayey marl and stone.	Probably as at Ilminster.	×	×	Blue clay. Pink limestone (thin band).

× No definite details available.

* The designations denote different beds in their correct order, except when between brackets, when they are explanatory of the following sentence.

† See footnote, page 459.

Considering the very great development of the Toarcian limestone in the Cotteswolds it may be advantageous to give a comparison of the strata of that district with a section of the strata in Dorset (fig. 2, facing p. 456). This correlation is entirely founded on the position of the different species of Ammonites; and for further information on this matter the reader is referred to my Monograph on "Inferior-Oolite Ammonites," Palæontographical Society, p. 91.

The horizontal diagram (fig. 3, p. 468) is intended to represent the Inferior-Oolite strata north and south of the Mendips, with their geographical extension according to the correlation just given, on a line from Leckhampton Hill to Burton Bradstock. Apparently the Mendip range must have acted as a barrier between the areas on each side of it; but it is more curious to find that a change in lithology in the Sodbury district, a change which I have demonstrated in the case of the sands, should coincide with an outcrop of Carboniferous Limestone. This is part of a patch which extends to Charfield and reappears across the Severn and no doubt formed, at that period, a subsidiary range of hills joining the Mendip axis at right angles.

However, the character which this figure brings into greatest prominence is the remarkable persistence of a hiatus or lacuna, due to the absence of certain strata, in the middle of what is called Inferior Oolite. This is the same hiatus which Eugène Deslongschamps finds in Normandy, and which he proposes shall mark the uppermost limit of his Infra-Oolitic marls; this is the same hiatus which Dr. Vacek says occurs over the continent generally, and which he proposes as the uppermost limit of the Lias; this is the hiatus which I, following d'Orbigny, propose to take as the dividing line between the "Toarcien" and the "Bajocien"; this is the hiatus which is accompanied palæontologically by the sudden exit of nearly all the Hildoceratidæ, or 'true Falciferi.'

One last subject remains to be dealt with, namely, the matter of mapping. In connexion herewith the proposed classification would introduce some advantages, and would certainly get rid of such anomalies as the same zone being mapped as "*Midford Sands*" in one county and as Upper Lias Clay in another; or, again, as "*Midford Sands*" at one place and Inferior-Oolite Limestone somewhere else. It would probably be best for this purpose to divide the Toarcian into Upper and Lower, although there is between them, lithologically, no marked break at any point, and, palæontologically, only a small one. This palæontological break occurs at the end of the *Opalinum*-zone with the extinction of the genus *Grammoceras*—only one species of which, I believe, survives into the *Murchisonæ*-zone. Therefore, the *Falciferum*-, *Commune*-, *Jurense*-, and *Opalinum*-zones form the Lower Toarcian. They would require the following changes among others, namely the abolition of the dividing-line now drawn between Upper Lias * and "*Midford*

* Throughout a large part of Dorset and Somerset the Upper Lias Clay is not mapped, although to a great extent it overlies what is marked as "*g* 2, Middle Lias." For instance, at South Petherton, it is exposed to a depth of nearly seven feet on the top of the Marlstone; but nothing is said about it on the map.

Sands," which is erroneous, and the merging of these two divisions into one—*Lower Toarcian* *—with perhaps a marginal note as to the position of "*the Sands*" in the various localities.

On the other hand, the *Murchisonæ*- and *Concavum*-zones in Gloucestershire, from the Pea-grit, or perhaps from the Lower Limestone, to the Gryphite-grit, would form the "*Upper Toarcian*;" and this horizon might be marked as *g* 4. Wherever the Upper *Trigonia*-grit (*Parkinsoni*-zone) is absent in the Cotteswolds would be *Upper Toarcian* and would cause considerable alteration. Part of Cleeve Hill, part of the district round Andoversford, part of Leckhampton Hill, Crickley Hill, part of Birdlip Hill, part of Haresfield and Frocester Hills, and, in fact, most of the outer edge of the escarpment would be *Upper Toarcian*. Part of the country round Corton Downs, in Somerset, and some part of the escarpment as it passes along, now in Somerset, and now in Dorset, would also be distinguished as *Upper Toarcian*.

I may just say a word concerning the Northampton Sands, and the sands below the Yorkshire Dogger. Although partly on the same horizon as the strata which have been mapped as "*Midford Sands*," these sands have been mapped separately. Part of the Northampton Sand, however—that round Duston—belongs to the *Opalinum*-zone, as I have been able to determine by an inspection of its Ammonites †. Mr. Thompson ‡ has attempted to show that the Upper *Leda-ovum*-beds upon which this rests—the top of the Upper Lias Clay of the district—belong to the *Jurense*-zone. I should be glad to admit this, if possible, as it would be an additional argument against the artifical definition of the "*Midford Sands*" as equal to the *Opalinum*- and *Jurense*-zones; but I am unable to do so. The species of Ammonites which he quotes (p. 83) from the Upper *Leda-ovum* beds are all characteristic of the *Commune*-zone; none of the characteristic *Jurense*-zone species are mentioned—not a single species of the genus *Grammoceras* which dominated that period. The Dogger Sands of Yorkshire overlie the *Striatulum*-beds. From an examination of some species of Ammonites kindly forwarded to me by Mr. Hudleston, I am able to confirm his view that they, in part at any rate, belong to the *Opalinum*-zone; and in part they represent the *Dumortieria*-beds. It would be correct, looking at their zonal and stratigraphical affinities, to place together the Yeovil and the Dogger Sands under one name—far more correct than to combine the former with the Cotteswold and Midford Sands. Both the Yeovil and the Dogger Sands occupy a similar horizon, namely *above* the *Striatulum*-beds and *below* the *Murchisonæ*-zone; while the Cotteswold Sands are *below* the *Striatulum*-beds. According to the present proposed classification, the Yorkshire Oolites up

* The tops of Ham Hill and Chiselborough Hill in Somerset—at present marked *g* 5, Inferior Oolite, and which ought, at least, to have been marked *g* 4, "Midford Sands," the same as the sands with shelly beds at Stoford, Babylon Hill, Bradford Abbas, &c., which are on the same horizon—would be marked as *Lower Toarcian*.

† "Inferior-Oolite Ammonites," p. 52. Palæont. Soc. 1888.

‡ "The Upper Lias of Northampton: Part VI.," Journal of the Northamptonshire Natural History Field Club, p. 54 (1888).

to the top of the "Middle Shale and Sandstone" (Hudleston, *op. cit.* p. 75) would be in the *Toarcian*—the *Lower Toarcian* would end with the Dogger Sands, and thence would be *Upper Toarcian*.

In the Midland Counties the Toarcian would include the Lincolnshire Limestone; above that would come the Bathonian, the Bajocian being entirely absent.

Conclusions.

We arrive at the following conclusions in this paper:—

1. That the yellow-sand deposits of the counties of Gloucester, Somerset, and Dorset are on different horizons, earlier in the North, and later in the South.

2. That it is best to retain the names Cotteswold, Midford, and Yeovil Sands as local names merely, and not to extend these divisions beyond the yellow micaceous sands.

3. That the term "*Midford Sands*" for the whole series is inapplicable, since it gives an idea of contemporaneity, which does not exist.

4. That on account of the different horizons at which the sands are developed, and on account of the fact that they occupy only a small part of the duration of sandy deposits in various places, the idea of considering them as passage-beds between the Lias and the Oolite cannot be entertained.

5. That it is incorrect to assign all these sands either to the Lias or to the Inferior-Oolite series.

6. That there is no continuous and marked geological or palæontological break either at the beginning or end of these sand-deposits, or even at the end of either the *Commune*-, *Jurense*-, or *Opalinum*-zones.

7. That the strata from the *Falciferum*-zone to the *Concavum*-zone inclusive form a very continuous series dominated throughout by the Hildoceratidæ, and marked off palæontologically from its predecessors or successors; and that at the end of this period there is a ready-made break, often marked lithologically, due to the absence of one or other life-zone.

8. That the term *Toarcian* is applicable to this series; and it should be erected into a distinct formation.

9. That the term *Toarcian* is commendable because it does not commit us to any definite opinion concerning the constituents of the strata, whether Clay, Sand, Limestone, oolitic, or otherwise.

10. That the term is preferable to "*Infra-Oolitic Marls*;" because the term "Marls" is anomalous when applied to the majority of English localities.

11. That to call the whole series "*Toarcian*" is preferable to placing the *Falciferum*-, *Commune*-, and *Jurense*-zones in the Inferior-Oolite Series, or to uniting the *Opalinum*-, *Murchisonæ*-, and the *Concavum*-zones with the Lias; because both of these plans suggest an anomaly.

12. That the term "*Toarcian*," as thus defined, should be regarded

as a division of the Jura-formation, or a separate formation in the Jurassic system.

13. That the Toarcian can be conveniently divided into Upper and Lower Toarcian, the former including the zones from the *Falciferum-* to the *Opalinum*-zone, and the latter the *Murchisonæ-* and *Concavum*-zones; while the division between them practically corresponds to the disappearance of the genus *Grammoceras*.

14. That the term "Cephalopoda-bed of Gloucestershire" is unscientific. It does not embrace any particular zone, does not begin or end with any Ammonite period, and, if we think of Sodbury, is not referable to any uniform lithology.

Discussion.

The President said that the paper showed a large amount of field-work in conjunction with palæontological research, and helped to prove that much had yet to be done in the stratigraphy of England. He commented on the interest attaching to the Jurassic system, where the zonal divisions were so well marked. Neumayr had enumerated 33 zones. In the International Geological Map of Europe, the base of the *Opalinum*-zone had been adopted as the lower boundary of Middle Jurassic. He doubted the advantage of admitting intermediate subdivisions like "Toarcian," and would prefer a conventional arbitrary limit.

Mr. H. B. Woodward commented on the biological character of the paper. In England the entire Jurassic series (locally) was conformable, and the question was whether our divisional lines should be drawn on palæontological or stratigraphical evidence. A zone might be regarded as a particular assemblage of species; but when traced for any distance these zones were found running into each other. He instanced especially the inosculation of the zones of the Lias, as showing there were no rigid planes of division. He had adopted the term "Midford Sands" because it met an acknowledged difficulty; and so long as people knew what it meant, he could not see any valid objection to its use. The lower portion of the "Sands" in the Bridport Cliffs was inaccessible; but the beds passed downwards into the Upper Lias, while the upper parts were more nearly allied to the Inferior Oolite. He referred to the difficulties in connexion with the naming of Ammonites, and concluded that, taking the Cephalopoda-beds and the "Cotteswold Sands" together, and as stratigraphically equivalent to the "Yeovil and Bridport Sands," the term "Midford Sands" ought not to be changed.

Prof. Blake considered that the Author had thoroughly proved his case, in so far as showing that the different "Sands" were not on the same horizon. With respect to the "Toarcien," he thought the suggestion by no means new. As regards the dividing-line between Lias and Oolite, he observed that in South Europe limestones were more abundant in the Jurassic rocks. We ought to pay some attention to lithological distinctions as indicating physical changes. A new fauna, and that by no means Liassic, made its

appearance in the Cephalopoda-bed, although the same Ammonite-groups remained. The Author surmised that the *Striatulus*-beds disappeared towards Burton Bradstock, indicating a palæontological break. In Yorkshire, the *Striatulus*-beds were in Liassic shales. No doubt the family Hildoceratidæ constituted a bond of union between Lias and Oolite; but if this principle were generally adopted, this would help to divide the Lias also. Hence his objection to the proposed "Toarcian."

Rev. H. H. Winwood declared that lithology was cast to the winds if we accepted the conclusions of Mr. Buckman's paper. However, he was glad that the Author had done away with the misleading name "Cephalopoda-bed." In addition to *Amm. striatulus*, found in the Midford Sands in a cutting near Bath, he had found portions of another Ammonite, apparently too imperfect for Mr. Buckman to define, and also portions of a Brachiopod defined by Chas. Moore as *Rhynchonella spinosa*. He did not fully recognize Mr. Buckman's section at Lyncombe.

Mr. Hudleston was glad to hear a confirmation of the first part of Mr. Buckman's contention from so good a palæontologist as Prof. Blake. Lately, whilst examining the Inferior Oolite of the south-west for a particular purpose, he had come to the conclusion that the Yeovil Sands were on a different horizon from those of the Cotteswolds; hence he could not think it was advisable to describe them by the same name, except on very general grounds. When Phillips selected the term "Midford" for the "Sands" generally, it was probable that he had not an intimate knowledge of any of them. As regards the real Midford Sands the only thing clear about them was that they lay above the *Striatulus*-beds, and were consequently more allied to the Yeovil than to the Cotteswold Sands. If *Rhynchonella spinosa* had really been found the Midford Sands would belong to the uppermost zone of the Inferior Oolite. It was suggested that this might have been *Rhynch. cynocephala*. In the section near Midford the beds of the *Parkinsoni*-zone rested directly on the Sands, showing the absence of the *Murchisonæ*- and *Humphriesianum*-zones; hence there could be no question of passage where such a break existed.

Mr. Buckman's proposal to establish the "Toarcian" at the expense of the Upper Lias and the Lower Division of the Inferior Oolite was scarcely practicable, though we were indebted to the Author for specifying the particular genera of the Hildoceratidæ which characterized the several series. In Dorsetshire the palæontological hiatus between the Lower and Upper Divisions of the Inferior Oolite was undoubtedly very great, and by no means confined to the Cephalopoda. But this could not outweigh the many considerations on the other side. If Mr. Buckman's views on this point were accepted the Inferior Oolite would disappear, the Upper Division being thrown to the Bathonian.

30. *On the* Production *of* Secondary Minerals *at* Shear-zones *in the* Crystalline Rocks *of the* Malvern Hills. By Charles Callaway, D.Sc., F.G.S. (Read April 17, 1889.)

[Plate XVI.]

Contents.

Introduction.

In an introductory paper * read before this Society in April 1887, I gave a rough sketch of the mode in which certain of the Malvern schists † were produced; but no attempt was made to offer a complete solution of the questions discussed. At the British Association in 1887 and 1888, and at the International Geological Congress in 1888, I briefly stated certain additional results, reserving particulars of the evidence for more detailed communications. One of the most important branches of the inquiry is the genesis of the respective minerals, especially of the micas. If, as I hope to prove, some of the most abundant minerals are of secondary origin, the ground will be cleared for working out the details of the problem in hand.

Minute particulars of rock-composition will rarely be necessary in this paper. The principal varieties of the Malvern rocks have lately been carefully described by Mr. Rutley ‡, and, furthermore, I believe that the question is to be settled rather by field-evidence than by the study of minute structure. Indeed, the chief results were decided in the mind of the writer before a single slide had been cut. Nevertheless more than 150 rock-sections have been prepared. Some typical examples of these were submitted to the skilled examination of Dr. H. B. Patton, assistant to Prof. Rosenbusch, of Heidelberg, and he has generously permitted me to incorporate his notes in this communication §. My thanks are also due

* Quart. Journ. Geol. Soc. vol. xliii. p. 525.
† By "schist" I always mean "crystalline schist."
‡ Quart. Journ. Geol. Soc. vol. xliii. p. 481.
§ Dr. Patton's identifications of minerals were in all material points identical with my own. A few cases in which we differed I have excluded from consideration.

to Mr. J. J. H. Teall for several valuable suggestions, and his admirable monograph * has been of much use. It is satisfactory to note that Mr. Teall has recognized † at the Lizard certain "banded gneisses" to which he assigns an origin similar to that of the "injection-schists" of my last paper; but I understand that he expresses no decision on the genesis of the granite-veins. Prof. Bonney has also favoured me with his opinion on certain points.

I. Structural and Mineral Changes produced at Shear-zones.

A. *Structure of a Shear-zone.*

As the production of new minerals is frequently connected with a differential movement in rock-masses, it is necessary to describe the nature of the shearing and the distribution of the sheared rocks. At Malvern, foliation (which in this district is ordinarily the result of shearing) occurs in bands of irregular breadth situated at irregular intervals. The zones may be a few inches or many yards broad, and the intervals between them may vary from a few feet to several furlongs. As the strike of the zones is usually transverse to the geographical axis, the length can rarely be ascertained; but in the Ragged Stone Hill a shear-zone which coincides in strike with one of the spurs can be traced for about half a mile. The gneissic structure usually shades off on each side of the zone into the ordinary igneous masses, and within the zone itself the metamorphism varies in intensity, bands of maximum shearing alternating with rock in which the original structure of the diorite or the granite has only partially been destroyed. The schistosity may exist in granite, diorite, or felsite; but the most interesting phenomena occur where diorite is interlaced with granite veins. These foliated bands may be described as "shear-zones." Their most frequent strike is to the north-west.

The proofs of mechanical force resulting in shearing are numerous and clear. Hornblende-crystals are drawn out into ribands, which are sometimes bent round crystals of felspar. Felspars are occasionally bent, but more frequently they are broken; sometimes the fragments are partially rounded, so that when immersed in chlorite and arranged in layers they present a curious mimicry of the coarse seams in a sedimentary rock. The effects of pressure increase in intensity towards the shear-zone, the crystals of hornblende being progressively elongated, the felspars, when not broken, becoming somewhat flattened, and folia of secondary quartz increasing in length and tenuity. Sometimes a crystal of hornblende breaks up along the cleavage-planes into numerous fragments, which are drawn away from each other along the direction of foliation, and tail out at the ends in a few widely separated particles. The interspaces are filled with other minerals; but the scattered parts of the broken crystals often extinguish simultaneously. "Strain-shadows" in crystals are very frequent.

* British Petrography, 1888.

† British Association Report, 1887, p. 707.

The differential nature of the movement is seen by taking a series of specimens along a straight line at distances of two or three inches. When we examine the slides in succession we can trace the stages through which a clear idiomorphic crystal of hornblende passes into an irregular opaque string of three or four times the original length. A similar change may often be seen even in the same slide. One side may be diorite, scarcely modified; the other, a schist.

The planes of movement (shear-planes) can frequently be observed. They sometimes appear in the slides as lines of actual separation sharply indicated by decomposition-products, such as chlorite or ferrite. At these lines the minerals have suffered their maximum of distortion and fracture. In a further stage of metamorphism, when decomposition has begun to give place to reconstruction, the slide is clearer, and frequently, in the case of diorite, black mica is formed at the shear-planes, so that the rock splits into thin leaves whose surfaces glisten with mica, while the interior of the laminæ may be dioritic. In a thoroughly reconstructed rock it is not always possible to detect the shear-planes. In some schists they are marked by lines of mica, and this is perhaps the most general indication.

B. *Schistosity in Diorite.*

Except in the contiguity of granite-veins, I have not observed that very material changes occur in diorite under pressure. Parallelism of structure, the production of shear-planes, the formation of decomposition-products, the distortion and fracture of minerals are the ordinary effects noticed in the Malvern district.

C. *Schistosity in Granite.*

On the margin of a zone the granite is crushed into a mass of subparallel wedges, which become progressively thinner and longer. In the bands of maximum shearing the cracks are healed up, and the ordinary gneissic structure appears. Much of the felspar is reconstructed in smaller crystals or in granules, and secondary quartz is produced. Very frequently white mica is also formed. This change is, of course, well known, and I have described it from a Malvern locality in my former paper (p. 528).

D. *Schistosity in Felsite.*

The felsite, already devitrified, progressively acquires a parallel structure, which becomes more and more marked, the individual granules breaking up into quartz and mica till a mica-schist is formed (*ibid.* p. 530). Variations occur in the schist, due apparently to the segregation of the acidic and basic elements respectively, so that while some seams are a quartz-schist, in others the mica predominates over the quartz.

E. *Schistosity in Veined Complexes.*

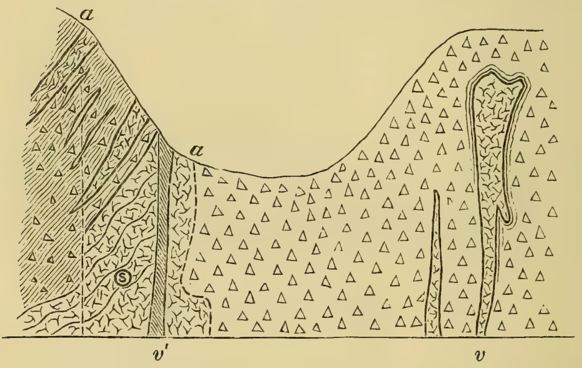
The most important phenomena occur in masses of diorite interlaced with granite veins and subjected to pressure.

1. *Production in Diorite of Black Mica, White Mica, Quartz, and Secondary Felspar.*

Shear-zone above West Malvern (Fig. 1).—This section is seen in the uppermost of several quarries at the more southerly of the two paths which cross over the ridge to Great Malvern. In the lower quarries the rock is mainly diorite with vertical granite-veins. The same structure appears in the greater part of the section; but just at the northern extremity shearing sets in. The diorite is one of the coarse varieties of my former paper, and is

Fig. 1.—*Section of Shear-zone above West Malvern.* (Scale 3 feet to 1 inch.)

N. S.



Granite. Diorite.

a–a. Joint-surfaces, facing to south.
s. Where shearing commences.
v. Vein with upper part sheathed in kersantite.
v′. Vein of quartz and biotite.

similar to a rock described by Mr. Rutley * as a "hornblende-gabbro." In its normal state it is a granitoid compound of hornblende and plagioclase, with perhaps an iron-ore and sometimes with apatite. The granite is the ordinary binary compound of quartz and red orthoclase, the only original granite I have ever seen at Malvern. Microcline † is sometimes found in it, but this mineral occurs so frequently in this district coincidently with crushing that I suspect much of it is of secondary origin. The veins vary in thick-

* Quart. Journ. Geol. Soc. vol. xliii. p. 492, No. 4.
† *Ibid.* p. 500, No. 22; p. 505, No. 33.

ness from several feet to two or three lines. Some of them have subparallel margins, others form slender tongues ending upwards in a point, while one is narrow below but swells out upwards into a club-shaped mass. Where the veins attain a thickness of a few inches they are encased in a sheath of kersantite (diorite modified by the contact), the mica being most abundant at the contact of the kersantite with the granite.

At the northern end of the section the veined rock passes rapidly into a banded gneiss, with a dip to the north of 70°. This sheared portion is about a yard wide, and probably extends further under the turf. The ground-mass (modified diorite) is blackish-green in colour, and is striped with several greyish bands (modified granite) varying in thickness from four inches to a line or two. The diorite and granite become progressively crushed towards the shear-zone; but where the oblique dip sets in, the parallelism of the constituents, whether rock or mineral, grows very marked, and there is much mineral replacement. The following are the chief changes to be noted:—

The granite (453 *) in the angle between the last vertical vein (v', fig. 1) and the first clear dip of gneiss already begins to display a parallel structure. The felspar is largely microcline, showing very clearly the cross-hatched structure. The longer axes of the larger crystals and one system of lamellæ lie in the direction of the rough foliation. The felspars are much corroded at the margins and in the interior by a water-clear mineral, probably quartz, so that idiomorphic forms are rare. There are also in the slide many small crystalline granules of microcline and of unstriated felspar, forming, with granular † quartz, thin irregular folia, such as are usual in a gneiss formed from granite. Quartz also occurs as long fingers running into and between felspar crystals, and, being parallel to the elongation of the latter, they accentuate the schistosity.

Another specimen of granite (405), taken just at the margin of the thoroughly schistose zone, has a more distinctly foliated aspect. The felspar, much of which is microcline, is in small granules. The granules of quartz are much larger and are elongated with the foliation. White mica, showing characteristic cleavage, parallel extinction, and vivid colours at oblique angles, occurs in crystals with sections (normal to the basal plane) whose four sides are about equal. Some of it is moulded on rounded granules of quartz, but sometimes quartz is moulded on angles of the mica.

A few inches within the zone, and near where the oblique dip abuts on the vertical veining, a band of the granite is sheared into a gneiss with thin regular folia, which are strangely contorted into almost circular folds an inch or two in diameter. This contortion appears to be due to the friction of the rock, during shearing, against the less yielding mass in contact with it. Under the microscope (408)

* The numbers in brackets refer to the slides in my cabinet.

† In view of the various senses in which the term "granulitic" has been used, I have throughout this paper refrained from employing it.

the folia are seen to consist mainly of alternations of quartz and felspar in small granules.

In the centre of the exposed part of the zone is another band of sheared granite (407). This is as much like a true gneiss as it can very well be. Seams of quartz, of a coarser grain than any of the preceding, alternate with seams of mixed felspar, white mica, and finely granular quartz. The felspars, of small size, unstriated and a little dirty, are in corroded forms or occasionally idiomorphic. The mica is abundant, and is usually in lath-shaped sections.

The changes here described are those commonly observed in the conversion of granite into gneiss. Felspar is reconstructed in small granules or in crystals, and white mica is produced out of it. Secondary granular quartz is also formed.

Diorite on the margin of the shear-zone shows the following characters. Hornblende is in large crystals of various shades of green and brown. Pleochroism is fairly strong, especially in sections parallel to the base, in which the double system of cleavages is very distinct. The sections which are approximately parallel to the sides of the prism show a tendency in the mineral to break up along the cleavage-planes, giving the well-known "reedy" structure. There is also some crushing and contortion of the crystals. A little chlorite is formed from the hornblende. The entire quantity of felspar is very small. Some of it shows the twinning of a plagioclose, but a large proportion is untwinned. It is mainly replaced by epidote and white mica. Spicules of hæmatite (or limonite) are abundant, and often occur in the white mica, lying parallel with the lamellæ.

Five slides (400–404) were taken, a few inches apart, commencing outside the visible zone, and proceeding to about the middle. The following changes were noted :—The hornblende becomes more and more "reedy" and broken up, and in one of the later slides it occurs in detached spicules (sections parallel to prism), in minute rhombic forms (sections parallel to base) and in various irregular fragments. The proportion of hornblende diminishes from about one half to one tenth of the slide. The felspar decreases in quantity till in the last of the series it cannot with certainty be detected, and in the last but one it occurs only in a small number of minute clear crystals and a few scattered granules which appear to be the eroded remains of crystals. It is sometimes striated, sometimes not. Its place is taken very largely by white mica. In the first slides the mica is seen to be penetrating the felspar from the side or wholly enclosed within it, and it shows a progressive increase through the series. It appears mostly in lath-shaped sections, whose longer axes lie in all directions in the earlier slides ; but in the later and more schistose specimens they tend to run with the general foliation. As the abundant appearance of white mica in diorite at shear-zones is a point of some interest, a diagnosis of this mineral from a similar rock-specimen will be given further on (No. 327, p. 493).

Epidote occurs in considerable quantity in all the slides. Much

of it is in irregular colourless granules, showing high refraction and brilliant polarization. Some of this mineral is in larger masses, in which can be detected prismatic forms with longitudinal cleavage and transverse jointing. Sphene is also present in characteristic wedge-like crystals, with very high refraction and a dingy roughened surface. Much of the epidote seems to have come from the hornblende. Chlorite appears in the earlier slides, replacing hornblende. Sometimes it encloses epidote. In the later slides there is a little chlorite banded with black mica, and a fair proportion of black mica occurs in irregular strings running with the foliation.

Quartz is not in quantity in the first four slides. It appears in granules invading the felspar. In the last slide it is very abundant, lying in well-marked folia alternating with the other minerals.

A careful study of this series shows that, especially in the later slides, most of the minerals are of secondary origin. We may assume that the breaking-up of the hornblendes into cleavage-prisms lying scattered in elongated patches is a secondary mechanical effect. Also it will hardly be denied that the chlorite and the epidote are the result of decomposition; they appear replacing hornblende in the clearest manner. Thus it is common for a part of an idiomorphic hornblende-crystal to remain intact while the place of the other portion is taken by chlorite enclosing epidote.

The black mica has apparently been formed from the chlorite. It appears, in the more schistose slides, banding chlorite and sometimes taking its place. Patches of the mica-crystals surround little nests of epidote, and the mica is moulded to the angles of the epidote, just as in the case of the chlorite. This is well seen in one of the later slides of the series (Pl. XVI. fig. 6), in which the hornblende has greatly decreased and the field is largely occupied by epidote. If the epidote is secondary, so is the biotite *. This mica is also moulded on fragmental hornblende in the same slide. Further evidence of the conversion of chlorite into black mica will be given later on.

The secondary origin of the white mica is very clear. It is moulded upon the jagged edges of bent and crushed hornblende-crystals, and where the crystals have opened along cleavage-cracks mica fills in the opening in the form of wedges. It frequently encloses epidote, and in one place it is interlaminated with chlorite.

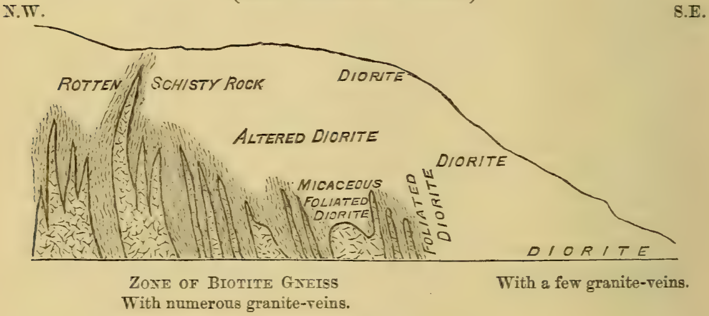
Most of the felspar also appears to be secondary. Plagioclase, clearly polysynthetic, and unstriated felspar are seen moulded upon the projecting angles of broken hornblende-crystals, and enclosing the minute prismatic fragments into which the mineral breaks up. Felspar is also moulded upon the angles of white mica. This felspar is clearer and sometimes in much smaller crystals than that of the original diorite, in which the felspar of the soundest rock is usually somewhat cloudy.

The secondary origin of the quartz I need not dwell upon.

* Prof. Lossen recognizes that "in granite and gabbro contact-zones" biotite is developed from chlorite derived from augite or hornblende ('Nature,' Sept. 27th, 1888, p. 528). The production of biotite as a contact-effect in sedimentary rocks and in some greenstones is, of course, well known.

Shear-zone at the south end of Swinyard's Hill (Fig. 2).—This section is seen at the eastern end of the large quarry on the road through the hollow between Swinyard's Hill and Midsummer Hill. The face of rock represented is 20 feet in length from south-east to north-west. In the lofty and precipitous slope rising from it to the north we see granite-veins, several feet in thickness, ascending amidst black diorite, and still higher up the ridge the granite swells out into masses, one of which furnished me with the gradation into muscovite-gneiss described in my last paper *. The veins above the quarry decrease in size towards our section, where they range between the breadth of a yard or so and the thinness of

Fig. 2.—*Section of Shear-zone at south end of Swinyard's Hill.* (Scale 6 feet to 1 inch.)



a wafer. Their number is countless. One large vein (not represented) reaches to the top of the low cliff: but the others terminate upwards. The thick veins usually give off several branches which rise almost vertically in straight narrow tongues ending in a sharp point, so as to resemble long spikes. This effect is obviously produced by pressure. Some of the thin veins terminate downwards also in a point. The veins represented in the figure are drawn with approximate accuracy; but most of the remainder are of such extreme tenuity and so closely interlaced that the attempt to copy them was abandoned.

The thin veins of granite frequently differ from the masses and larger veins in their greater acidity. In the field-examination of a plexus of veins we often see that the thinner ones are partially silicified, and sometimes they are converted into pure quartz. The nature of the process, as seen under the microscope, will be described further on (p. 498). In other cases the enclosing diorite has transferred some of its basic matter to the granite, the orthoclase of the vein being penetrated to a greater or less distance by crystals of striated felspars.

We return to our section. The right (south-eastern) end of the low vertical face of the rock consists of the "medium-black" diorite

* Quart. Journ. Geol. Soc. vol. xliii. p. 528.

(No. 1 of my former paper, *loc. cit.* p. 526), the most abundant variety of diorite in the Malvern Hills. It is penetrated irregularly by a few granite-veins. Towards the left, as we face the section, veins of granite come in more numerously. Signs of pressure also appear, and increase towards the zone in which the mixed diorite and granite are rolled out into a banded micaceous gneiss. The rock above the level reached by most of the veins in the sheared part is schistose, but much decomposed *. Further back towards the unsheared end, where the veins are fewer, sound diorite appears within a yard or so of the upward termination of the veins. The unsound rock, which here (and frequently elsewhere) forms a sort of aureole round a plexus of veins, is largely micaceous and chloritic.

The following series of slides illustrates the transition from diorite to mica-gneiss. By the "edge" or "margin" of a shear-zone or sheared complex, I merely mean the boundary-line between the undoubted gneiss of the zone and the more or less sheared rock which graduates up to it.

Four specimens (273–276) were taken near together from the diorite 3 feet from the zone. They consist of about half hornblende and half felspar. The crystals of the former rarely present perfect forms, being usually rather jagged or corroded at the margin. Some have undergone mineral change, having liberated iron-oxide as an opaque stain, or being partly converted into chlorite, especially along cleavage-planes. Plagioclase can be here and there detected, but much of the felspar displays no twinning. In some of the crystals are many microliths of a clear transparent mineral, probably white mica, and larger patches of white mica. There is some cubic iron-ore and a little sphene, the latter either free or incrusting ilmenite. Nos. 274 and 276 are cut respectively from the same hand-specimens as 273 and 275, at, or near, contact with small granite-veins. They show a tendency towards parallelism and aggregation of the constituents. This is especially seen in the hornblendes, which here and there occur in folia of from half a dozen to a dozen crystals variously orientated. Some of the crystals are also much larger than in 273 and 275. In respect to parallelism, aggregation, and enlargement, the rock close to the veins forms a connecting-link between the ordinary diorite and some of the gneissic rocks which follow in the series.

Nos. 311 and 312, taken 18 inches from the shear-zone, show characters similar to those of 274 and 276, with the following differences:—The slides are altogether much clearer. The hornblende lies in folia of irregular thickness, and the crystals are sometimes drawn out in the direction of schistosity. They frequently present curvilinear outlines in a very marked degree, and are perforated by holes usually occupied by a water-clear mineral. I suppose these peculiarities are the result of corrosion; but if they are produced during recrystallization under new conditions, the distinction is not very material; they do not characterize the unmodified diorite, and

* This unsoundness, occurring, as it usually does at Malvern, at the most critical points, renders it extremely difficult to obtain satisfactory results.

must be regarded as the effect of secondary action. This hornblende, compared with that of the preceding slides, is darker, brighter, clearer, and more strongly pleochroic. Chlorite sometimes appears in the cleavage-planes of the hornblende, and increases in quantity at some points so as to form nests of rosettes, irregular blotches, or patches running with the foliation. Under crossed nicols it gives a deep indigo-colour, passing into grey. In one of the slides there is a fair quantity of epidote.

Much of the felspar is clear and sound, and a large proportion of it shows the twinning of plagioclase; but some of it has begun to break up into an indistinct mosaic, and displays numerous microliths of a clear mineral (white mica?). It is important to note that this felspar is moulded upon all the preceding minerals, and even includes shreds of the chlorite and minute fragments of broken hornblende-crystals. The chlorite is certainly derived from the hornblende, and the distortion and fracture of the hornblende is a secondary result produced by pressure subsequent to consolidation, since, as I have stated, it is frequently connected with the formation of planes of discontinuity. That this felspar is secondary receives some confirmation from its clear and fresh appearance.

The slides contain a small proportion of granular quartz, some of which contains liquid-cavities with air-bubbles.

No. 314 is taken from within a few inches of the veined plexus. Much of the hornblende is dragged out in the direction of foliation, and the whole of it is more or less dirty and opaque. The opacity is apparently due to liberated ferric oxide. Most of the felspar is either cloudy or contains countless clear microliths (white mica ?), and in some there are patches of white mica. There is also a great quantity of finely granular, almost opaque, matter in the felspar. It may be epidote or zoisite. Granules of quartz are scattered through the slide.

No. 391. About the same distance from the zone, but a little higher up. The hornblende is like the last, but the curvilinear outlines may be sometimes made out. The felspar is also similar. The proportion of granular quartz is greater. The noteworthy feature of the slide is the coming-in of black mica. It occurs in elongated flakes several laminæ in thickness and pointed at each end. They run parallel to the general foliation, often passing through the middle of hornblende-crystals, and are occasionally associated with a little chlorite. The habit of these flakes is precisely that of the chlorite, which forms in the interior of the hornblende, and frequently projects beyond it. The felspar is clearly moulded upon the mica, and sometimes completely encloses it.

No. 316 is in contact with the shear-zone. The rock is rather more compressed than in the last two slides. The hornblende is similar. It sometimes passes into chlorite, which becomes banded here and there with black mica or is entirely replaced by it. Sometimes a little opaque flake, probably ferruginized hornblende, projects from a bit of hornblende into a patch of chlorite, and just round the margin of the flake black mica is formed, showing marked

dichroism. The place of the felspar is mainly taken by quartz and white mica, the latter of which is much more abundant than the biotite. Owing to the progressive development of these micas towards one side of the slide, the modified diorite passes into a mica-gneiss.

No. 313 (Pl. XVI. fig. 1) was taken from the edge of a rather large granite-vein, 12 inches from the plexus, to show the effect of the granite upon the diorite, even where the compression is not very great. The slide includes part of the vein, with a sheath of what was once diorite, but is now a sort of kersantite, with a semi-gneissic structure due to the laminæ of the biotite and the longer axes of the felspars being orientated parallel to the margin of the vein. The felspar crystals are like those of the adjoining diorite (Nos. 276, 312). Most of them are very cloudy, but some are clearly twinned like a plagioclase. The biotite forms a sheath round the felspars, and sometimes thickens out into crystals as broad as long. Dichroism is strong, the mica being nearly black when the striæ are parallel to the principal section of the nicol, and clear brown when at right angles to it. A little chlorite is banded with it. This mica is massed together in linear bundles of larger crystals at the contact with the vein. The felspar of the vein is in the usual large crystals, which are cloudy and with ill-defined outlines. Some plagioclase is present, penetrating the orthoclase from the outside irregularly. The quartz sometimes appears running into the felspar in little streams which narrow inwards like estuaries.

No. 319 is from the edge of the plexus, and includes part of a granite-vein. The characters are similar to those of the last, with the effects of pressure added. The kersantite contains a little white mica and, as often happens when this is the case, some chlorite. The same kind of kersantite as in No. 313 appears on one side of the vein; but on the other the biotite runs together into irregular folia. Some of the felspar of the kersantite is replaced by a water-clear mineral which polarizes like quartz, and, in convergent light, shows a dark bar which remains straight during rotation of the stage, and the sheath of mica often retains its place round these replacements of quartz. The felspar-crystals which are only partially replaced have curvilinear margins. In other parts of the slide there is a tendency to aggregation; biotite, quartz, or felspar occurring in patches of a roughly oblong shape. Where the quartz predominates, the structure is that of quartzite, a few mica-flakes, with orientation parallel to the rest of the mica in the slide, or eroded felspar-crystals, being scattered through the ground-mass of irregular quartz-granules. But the gradation between the kersantite and the gneissoid quartzite is complete. The changes of the kersantite in this slide, as in many others, are towards either biotite-gneiss or gneissoid quartzite. In the former case the mica is aggregated into more or less regular folia, and the felspar is partly replaced by granular quartz; in the latter the change into quartz is carried further, and the mica is almost wanting. There is nothing special about the granite-vein, which is irregularly outlined by black mica. The orthoclase is penetrated on one side by plagioclase.

No. 277 (Pl. XVI. figs. 2, 3) was selected from the core of the plexus as a specimen of a sound typical gneiss. Bands of foliated kersantite (fig. 2) alternate in the slide with a granite-vein or two and with the quartzitic gneiss (fig. 3)*; but the micaceous material graduates into the more quartzose along the strike as well as transversely. The passage between the kersantite and the quartzose gneiss is, indeed, as complete as possible. There is a larger proportion of white mica than in No. 317. A part of it is not orientated with the biotite; indeed, some small crystals of it, included in the black mica, lie with their laminæ almost at right angles to those of the biotite. The felspar crystals of the kersantite sometimes coalesce into bands alternating with the biotite. Amongst them is a little microcline, and as this mineral has not been detected in the normal diorite it is probably secondary.

A vein of granite passing across the slide is of some interest. A crystal of the orthoclase has several cracks in it. One of them is nearly 7 mm. in length, and is filled up almost to the inner extremity with black mica. Two or three smaller ones are similarly occupied. It appears to be a highly probable conclusion that this mica was injected subsequently to the intrusion and consolidation of the vein, since it is continuous with the mica of a seam of kersantite. Further information on this head will be given in the section on infiltration (p. 496).

No. 318, from the central part of the zone, is almost a quartzite. At the edge of the slide is the foliated kersantite, but the felspar is invaded here and there by quartz-granules. The quartz increases in quantity towards the other side, so that some parts of the slide consist of about three fourths of quartz-granules, and one fourth of cloudy felspar with sinuate margins: a few scraps of biotite, the mere rags of the usual flakes, being scattered about.

The conversion of a diorite into such an acidic rock as a gneissose quartzite, improbable as the change may seem, receives support from an interesting fact recorded by Professor Zirkel †. He says that "quartzite as white as snow is interstratified in the hornblende-gneisses at the north end of the Park Range." The quartz of the former contains numerous fluid-inclusions, which "belong to two different varieties, some being composed of water with a moving bubble, which does not disappear in a temperature above 100° C., and others being the double inclusions ‡, with carbon dioxide in the interior, whose bubble may be driven off by the smoke of a cigar. It is remarkable that these inclusions of different chemical nature are associated also in the quartzes of the accompanying gneisses, a fact which may perhaps prove that the nearest geological connection exists between the two rocks, and that in origin they are the same." The two kinds of rock referred to by Prof. Zirkel are not much more widely different than the two extremes of the series I have just described.

* This figure does not show the extreme of acidification, but was selected because it retained remains of the kersantite structure.

† 'Microscopical Petrography,' Washington, 1876, p. 33.

‡ Described on pp. 18, 19, consisting of an outer solid zone, distinct from the matrix, containing liquid carbon-dioxide.

The two shear-zones of which I have here given an account may be taken as types. In the former the production of white mica in the soda-lime felspar is perhaps the most prominent character; in the latter the conversion of hornblende into biotite is the most striking feature. The reconstruction of plagioclase and the generation of granular quartz is seen in both. These veined complexes give us the "injection-schists" of my former paper (p. 532).

I am not prepared to explain why the schistosity of the Malvern region is zonal; but I think the frequency with which a shear-zone coincides with a veined complex can hardly be accident. Though there is shearing in granite only, and in diorite only, it is more common where the diorite is interlaced with veins, especially small veins. Shearing would, of course, occur at weak places in the crust, and it would seem that a veined complex should more readily yield to pressure than a homogeneous mass; or both veining and shearing may be results of an original weakness.

Parallelism in the arrangement of minerals without regional pressure has been noticed by previous writers. Thus, in sedimentary rocks altered at their contact with granite-veins there is sometimes a production of minerals in lines parallel to the margins of the veins. We have seen this principle illustrated in Nos. 274 and 276, and similar examples frequently occur at Malvern. But this cause is only of local effect, and it cannot account for the general schistosity of the Malvern rocks.

The phenomena here described from two localities are common throughout the Malvern Hills. The most obvious fact observable in the field is the production of the biotite. Granite-veins, if of large size, that is, 6 inches or more in diameter, are often surrounded by a sheath of kersantite two or more inches in thickness. Indeed, so uniform is the effect of the contact that the vicinity of veins may usually be safely inferred from the appearance of biotite in the diorite. Thin granite-veins, unless very numerous and close together, or accompanied by shearing, do not always produce biotite; they may give rise merely to decomposition without subsequent synthesis. If the veins are abundant or large, the chlorite nearest the granite is banded with black mica, or is entirely replaced by it. I am not satisfied that hornblende in this district is ever converted into biotite *directly*.

Shearing has greatly intensified the metamorphic effects of the granitic intrusions. The production of biotite at shear-planes may only in part result directly from mechanical energy. The shear-planes would certainly permit the infiltration of mineral solutions, and these might of course give rise to chemical reactions. But some direct proof of the infiltration of mineral matter will be given further on (p. 496).

2. *Further Mineral Changes: White Mica from Biotite and from Chlorite; Garnets and Zoisite; Sphene; Actinolite; Hæmatite; Calcite.*

White Mica from Biotite.—This change has been noticed by writers

from Bischof downwards. In ordinary decomposition, the biotite usually passes into chlorite, but such an alteration would be obviously impossible in the environment in which the biotite has been produced, and any mineral change must be in another direction. There are frequent indications in the Malvern Hills of the conversion of biotite into white mica. The evidence is of two kinds. In some slides, in which seams of chlorite alternate with other minerals, chiefly felspar and quartz, and where the shearing increases in intensity towards one side, the chlorite is represented in the intermediate zone by biotite, and in the most schistose seams by white mica. These slides will be more fully noticed in the next section. Again, black mica appears to pass into white mica in the same crystalline form. The crystals observed were cut normal to the basal plane and were lath-shaped. One half or so of the length of the lath was brown, with strong dichroism; the other transparent, without pleochroism, and polarizing in bright colours of the first and second orders. Yet the margin of the lath-section was bounded by parallel straight lines, the parallel cleavages passed uninterruptedly from end to end of the section, and both micas extinguished simultaneously. It would appear more probable that we have here a case of alteration than of simultaneous crystallization. The change from biotite to white mica is associated with the intrusion of granite-veins, as noticed by MM. Fouqué and Lévy *.

White Mica from Chlorite.—This transformation was an unexpected one; but the changes from chlorite to biotite, and from biotite to white mica, remove a great part of the antecedent improbability. The facts here described were observed at the Ragged Stone Hill. In a certain stage of metamorphism we get a schisty rock, mainly consisting of chlorite alternating with fragments of broken crystals of triclinic felspar. This schist is penetrated by granite-veins. How this rock was produced does not concern us in the present paper. Following the field-section in one direction, a progressive change is seen; the rock becomes more and more schistose, and in the advanced stage the foliation surfaces glisten with films of mica, and sometimes there is great contortion. The felspar fragments in this stage are sometimes intact, but they are often replaced by a colourless, transparent, rather highly refractive mineral, which I have not yet fully studied, and by minute water-clear granules with the polarization of quartz, and some of them at least are uniaxial. The felspar is thus mostly accounted for. The chlorite sometimes passes into black mica, as stated in the preceding section; but where the shearing, as evidenced by increased schistosity and by the distortion of calcite-veins, is very great, the change is directly into white mica. In one slide (303) the chlorite is largely represented by biotite, which towards one side, where the schistosity is greater, passes into bundles of a white mica (sericite?), with included opaque lines (iron-oxide?) running in the same direction as the films. Within a few inches, the rock is wholly schistose, with glistening mica-surfaces. Very little biotite is present, but there is an abundance of white mica in patches of undu-

* Minéralogie Micrographique, p. 339.

lating sericitic bundles thickest in the middle. Its colours of polarization are clear and vivid, not in uniform sheets, but with a rather blotchy aspect, except when the fibres or laminæ are distinctly defined. This mica is associated with chlorite. The latter sometimes occurs in small isolated patches; but a large proportion of it surrounds the mica-bundles, and lies within them, sometimes in irregular blotches. The chlorite of some of these blotches gradually passes into the non-fibrous part of the mica. By plain light the green colour of the former is seen to be densest in the middle of the blotch, and it shades off into the transparency of the enclosing mica. Under crossed nicols the chlorite is of a mottled black colour in the centre, and it graduates outwardly into a grey, which shades through white, orange, and red into the blues and greens of the second order. The nucleus of the chlorite-blotch remains dark during an entire rotation of the stage, the mica extinguishing as its fibres are brought into parallelism with the axis of a nicol. A large quantity of opaque matter in irregular angular particles is enclosed in both chlorite and mica, and is probably part of the iron-oxide liberated in the general metamorphosis. The fine lines in the white mica probably also indicate liberation of iron.

Other slides from the same band of rock show a more complete change, the mica being in still greater proportion and the chlorite being nearly or entirely absent. I am unable to explain the facts here described except on the supposition that the mica has been formed from the chlorite.

The possibility that the mineral which I have described as mica was talc at first occurred to me; but two analyses of this schist, kindly made for me under the direction of Dr. G. H. Bailey, of Owens College, Manchester, giving respectively only 1·29 and 0·35 per cent. of magnesia, forbid the supposition.

Garnets and Zoisite.—Garnets are not common at Malvern, as only three or four slides in my collection contain them in noticeable quantity. No. 357 is from the crest of Swinyard's Hill, south of the summit. It is modified kersantite with two parallel granite-veins included. At one side of the slide is a highly quartzose vein, only a few shreds of curvilinear felspar remaining, and the second vein, which is at the opposite side, is entirely of quartz. The intermediate foliated kersantite becomes progressively quartzose towards the latter. At first it contains little quartz, then the felspar is more and more replaced by quartz, till, in some parts of the slide, the quartz is to the felspar and mica in the proportion of five or six to one. At the contact with the quartz-vein the felspar is rather more abundant. In the more quartzose, and presumably the more altered, parts, there is less black mica than usual, and garnets appear; they are also abundant round the margin of the quartz-vein. They are of small size, the largest being not more than 0·2 mm. in diameter, mostly in single or compound granules of irregular form, translucent or rather cloudy, showing strong refraction, and, between crossed nicols, remaining dark during an entire rotation of the stage.

No. 356 is from another part of the same mass. A part of the

slide has a structure resembling modified kersantite; but both biotite and felspar have nearly disappeared, and the rock is mainly composed of granular quartz, with scattered zoisite, replacing felspar, and garnet, possibly representing the mica. The mineral which I take to be zoisite is in irregular translucent granules, and its refraction being high, it resembles a garnet in plain light; but under crossed nicols it polarizes rather faintly in shades of indigo, passing through grey and white to yellow.

No. 417, from the Wych, is crushed granite with infiltrated chlorite. There are numerous garnets, some of which are traversed by irregular fissures filled with chlorite. Most of them are immersed in chlorite; but a small proportion of them are enclosed in felspar.

In the above slides, garnets, as well as the zoisite, appear to be the result of secondary action; for in the earlier slides they are seen only in the most highly altered diorite, and in the last they would appear either to have been introduced with the infiltrated chlorite or subsequently formed out of it. There has evidently been some reconstruction of the felspar of the granite after the garnets were formed.

Ilmenite and Sphene.—Mr. Teall called my attention to the association of sphene with some of the iron-ore of Malvern. I followed out this hint through 50 or 60 slides, with some interesting results. The ore (ilmenite) sometimes shows rhombohedral forms, simple or twinned, but is more frequently in irregular granules. It is very often incrusted with a whitish, finely granular substance (leucoxene); but as the rock (diorite) undergoes progressive alteration, the leucoxene becomes more coarsely crystalline, minute sphenoid forms appearing in the granular crust and increasing in size, till we are able to distinguish the high refraction and double refraction of sphene. These observations thus confirm the opinion of MM. Fouqué and Lévy * that the incrusting leucoxene is a form of sphene. As the sphene increases in quantity in the altered diorite, the ilmenite diminishes, until in some cases it is represented by a cluster of granules or crystals of sphene, with a little opacite. It is not asserted that *all* the free sphene is formed from ilmenite. Very commonly, slender sphene-crystals, clearly derived from associated iron-ore (335), lie in the cleavage-planes of chlorite. In an advanced stage of the metamorphism of diorite, when the rock has become micaceous (333), the cleavages of the mica, and the planes of junction between separate crystals of mica, are often occupied by dark lines, which, on examination with a high power, are seen to be acicular or vermicular microliths of a colourless anisotropic mineral with black margins, as if highly refracting, and sometimes crossed by dark lines, like jointing. It can hardly be doubted that this mineral is sphene.

The history of this sphene tends to confirm the evidence for the secondary origin of the black mica. Much of the sphene is certainly formed from ilmenite †, and the position it occupies in the cleavage-

* Minéralogie Micrographique, 1879, p. 426.

† It is not affirmed that the ore associated with sphene may not sometimes be titaniferous magnetite.

planes of the chlorite and the mica points to the secondary origin of both of these minerals. If, on the other hand, the mica is an original product, we seem driven to reverse the series of changes, and to conclude that the sphene of the mica, and subsequently of the chlorite, is changed to ilmenite and enclosed in hornblende, for the granular leucoxene, with its nucleus of ore, is often more or less surrounded by that mineral.

Actinolite.—Near the summit of the Ragged Stone Hill is a rock which Mr. Teall considers * "identical with many Cornish epi-diorites," such as have been described by Mr. Allport, Mr. J. A. Phillips, and more recently by himself †. Three specimens were taken along a line parallel with an adjacent felsite-dyke. One slide (343) contains uralite, actinolite, epidote, and felspar. The uralite rarely presents the true form of augite, but is usually in irregularly tabular sections with rounded angles. It is feebly pleochroic. It shades off, often in the same crystal, into acicular actinolite, which entirely replaces it in some parts of the slide. The epidote is in numerous highly polarizing granules. The felspar is tolerably clear, displaying no twinning, and merely filling in spaces between the other minerals, often enclosing spicules of actinolite and grains of epidote. It is obviously secondary, as observed by Mr. Teall ‡ with reference to a similar rock near Tavistock.

A second specimen (342), a few feet to the north in the same mass, is almost exclusively composed of actinolite and felspar in about equal proportions. It is semi-schistose, this structure being due to a rough parallelism of the spicules of actinolite, which often coincide in direction with irregular undulating lines of fracture (shear-planes). Some of the felspar is in elongated prisms and shows polysynthetic twinning.

A few feet further to the north, and continuous on the strike with the last-named rock, is a narrow band of a green schist (345), enclosed between two bands of felsite. It is more distinctly schistose under the microscope than the last, and the green mineral, which is apparently actinolite (see Dr. Patton's note, p. 494), is not so distinctly acicular, but runs in irregular strings. The felspar shows no twinning, and some quartz appears to be present. We have here, as in many of the preceding cases, the combined effect of contact and shearing.

Hæmatite occurs most frequently in the coarse grey diorite, and is usually enclosed in the chlorite formed from hornblende. It is often associated with ilmenite and leucoxene in such a way as to suggest that it sometimes results from the alteration of the former. It appears in bright red blotches or in lath-shaped sections, orientated with the cleavage of the chlorite or biotite.

Calcite is frequent in altered diorite, and in the schists which result from further metamorphic action. It is a decomposition product of both hornblende and felspar.

Apatite and *Magnetite* are often noticed in Mr. Rutley's paper on

* *In literis.* † Brit. Petrogr. p. 235. ‡ *Ibid.* p. 235.

the Malvern rocks; but I have not been able to find that they have any material bearing on my inquiry. Some of the latter is probably secondary, but a part of it is apparently original.

3. *Descriptive Notes on some of the Minerals by Dr. H. B. Patton.*

I am permitted to use these notes at my discretion. I have strictly confined myself to the descriptive matter of Dr. Patton's letters, but I have added such remarks as are necessary to connect his observations with my line of inquiry. The extracts will be indicated by inverted commas.

Passage from diorite (medium black) to muscovite chlorite-gneiss (Nos. 325, 326, 327). The specimens are from a quarry on the old road below the Wych, on the east side. The diorite is interlaced with a few large granite-veins. The slides are taken in order; 325 being 12 inches from a thick vein, 326 and 327 within 3 inches.

"No. 325. A compact rock, showing no trace of schistosity, with the structure and composition of a diorite. The principal mineral, forming about half the mass, is hornblende, showing little tendency to idiomorphic forms. Here and there, however, we can recognize the faces $\infty P = (110)$ and $\infty P\infty = (010)$. The outlines are irregular, wavy, and jaggy, as is generally the case with diorite-hornblende. The ends are often ravelled out into a fringe of needles. It possesses the cleavage-characteristics of hornblende, and also the high index of refraction and moderate interference-colours. It is mostly fresh, or, at most, changed along the cleavage-planes to little scales of chlorite.

"Feldspar is very much decomposed, mostly to very small, irregular, nearly colourless grains, possessing the very high refractive powers and the brilliant interference-colours of epidote. The original plagioclase-twinning has totally disappeared.

"Quartz in rounded grains is very abundant, and easily recognized by its clear colour.

"Biotite is apparently wanting, but a few scales, showing the properties of the muscovite in No. 327, are scattered about.

"Grains of magnetite or possibly ilmenite are scattered abundantly through the slide. They are often associated with grains of great refractive powers resembling sphene.

"No. 326. This rock has a similar composition to 325, but a schistose structure has been impressed upon it by the drawing-out of the hornblende and, to a still greater degree, of the chlorite. The latter appears to have been formed at the expense of the hornblende, occasionally almost totally replacing it. The chlorite is positive in character, and is easily recognized by its low interference-colours as well as by the characteristic pleochroism, the rays vibrating parallel to the cleavage being green, and those at right angles to the same yellow or reddish to colourless. It is deposited along the cleavage-planes of the hornblende.

"Feldspar, as in 325, is very much decomposed, being changed to small grains . . . . of epidote.

"On one side of the slide are many little scales of a colourless mineral showing same characteristics as are seen and described in 327.

"When the schistose structure is plainest, the chlorite appears banded with lamellæ of biotite, which are recognized both by strong pleochroism and by the very high interference-colours. The hornblende has almost entirely disappeared.

"Quartz is apparently wanting. Calcite is present in scattered grains.

"No. 327. Hornblende has almost totally disappeared, only small fragments being left surrounded by chlorite. The latter is very abundant, and by the parallel arrangement of the plates gives an eminently schistose structure to the rock.

"Biotite is scarcely noticeable, while the muscovite, noted sparsely in 325, and frequently in 326, is here very abundant. It is negative, the axis of greatest elasticity being at right angles to the cleavage. It is not attacked by hydrochloric acid. The very minute scales, isolated from rock-powder by means of the heavy solution of iodide of mercury and iodide of potassium, give upon the cleavage-faces in convergent polarized light a vertical negative bisectrix with moderate axial angle, such as muscovite generally shows. The size of the axial angle excludes talc. Feldspar is apparently entirely changed into a very fine mass of epidote grains. Calcite, as in the last, occurs in scattered grains. The rock effervesces with hydrochloric acid. Reddish scales of iron-oxide and grains of magnetite or ilmenite are abundant. The last are generally surrounded by a zone of titanite.

"The above-mentioned muscovite never shows a tendency to be intergrown with chlorite as is the case with biotite."

The series just described was selected to show in a compact form some of the changes produced at an igneous complex, but there is no good shear-zone here, and the metamorphism has not been carried to a very advanced stage.

No. 328, from the ridge north of the Wych, shows the same variety of diorite penetrated by a few minute granite-veins, three of which appear in the slide. It was selected to illustrate the fact that the degree of metamorphism bears some proportion to the number and size of the granite-veins *plus* the amount of shearing. Here the forces are acting with comparative feebleness, and the result is some decomposition, but little recomposition.

One side of the slide is diorite, which "shows a less degree of change in structure and composition than any of the foregoing (325–327). The twinning of the plagioclase is easily recognizable, and the hornblende is tolerably fresh and unaltered." "Quartz has been developed in considerable quantities. It is apparently secondary in origin. Feldspar is partly changed to epidote." "At the junction of this band with the granite-veins, the diorite is sheared, and at the same time much decomposed. Hornblende is replaced by chlorite. Larger crystals of epidote are developed at the junction with columnar form. In addition to the above-men-

tioned properties, we can notice that the axial plane is at right angles to the longest axis, and that the extinction is parallel or at right angles to the same. The other diorite-bands partake of the nature of this sheared portion in that they show much chlorite and epidote, the former occasionally interlaminated with black mica."

Identification of the actinolite (?) in the green schist near the summit of Ragged Stone Hill:—

"I think this is actinolite on account of the following properties:—Pleochroism marked green-yellow, with the least absorption at right angles to the longer axis of the crystals. The longer axis is also axis of least elasticity. The mineral shows further moderately high index of refraction (judging from the roughness of the surface) and double refraction."

4. *Exogenous Origin of the Granite-veins.*

It is of the first importance to determine whether the veins are segregatory or intrusive. That they are coarse-grained compounds of orthoclase and quartz would rather suggest an endogenous origin; but the following evidence seems to establish their intrusive character.

a. *They appear as Apophysès from large masses.*—We have seen that at the southern end of Swinyard's Hill the plexus of veins in the shear-zone is in close proximity with the larger veins which penetrate the diorite in the unsheared rock above, and these large veins are succeeded at a short distance by masses several yards in breadth. Many smaller veins occur amongst the masses, and both veins and masses are occasionally sheared into gneiss. Similar granite is found at intervals along the ridge, and towards its northern end the granite swells out into a mass extending along the axis for several hundred yards. There is no reason for believing that the veins have a different origin from the masses, and it is not easy to believe that the latter have been formed by segregation.

b. *They have the same Texture in different kinds of Diorite.*—The same granite is found in the two chief kinds of diorite. It is the same large-grained binary compound when enclosed in the coarse diorite of the North Hill and Worcestershire Beacon as in the fine-grained black variety of Wind's Point and Swinyard's Hill. We should hardly expect a granite or pegmatite of the same texture to be segregated from magmas, one of which is (roughly speaking) three times as coarse as the other.

c. *They produce Contact-effects similar to those of intrusive Veins.*—The action of granite-masses on diorite in contact has been described by Dr. Ch. Barrois. The following are the chief effects noticed by him*:—

(1) Abundance of quartz in large distinct irregular grains.

(2) Much alteration of the crystals of felspar, which are filled with quartz-granules, and epigenized by calcite.

* Le Granite de Rostrenen, p. 104.

(3) Uniform distribution of black mica, which he regards as of secondary origin.

Dr. Barrois, in answer to my inquiry, informs me that the quartz-granules occur also in the hornblende. These changes are strikingly similar to those produced under like conditions at Malvern.

I have investigated contact-effects on material from my Galway collection. Six slides were cut; they are from the fringe of the great mass of granite north of Galway Bay, where the granite sends veins into the diorite. In a previous paper * I have shown that the granite was injected into the diorite along the joints. All the specimens are from the actual contact, and contain both granite and diorite.

Four slides are from the summit of Lettershinna, where there are no marked signs of pressure. The following are the characters noticed in all:—

(1) The hornblende of the diorite nearest the granite is more or less perforated, and the margins are cut into sinuate or dentate outlines. The mineral in the holes and in contact with the irregular margin is often water-clear. In a few cases it shows the twinning of plagioclase.

(2) Near the granite, the place of the hornblende is often taken by chlorite. It is pale green, slightly pleochroic, and of a deep indigo-colour under crossed nicols.

(3) The chlorite contains some granules of a colourless, highly refracting, brightly polarizing mineral, probably epidote.

(4) Very rarely, the chlorite is interbanded with a brown mineral, which has the appearance and dichroism of biotite.

A specimen from the summit of Knockseefin displays signs of pressure. The hornblende is aggregated into irregular undulating folia lying roughly parallel to the line of junction. Some of the crystals are dragged out in the same direction. Perforation is common. At the junction, the hornblende passes into chlorite, occasionally banded with well-marked biotite and containing some epidote.

The sixth slide is from the south of Glendalough. The rock, in hand-specimens, shows a rough foliation. The hornblende of the diorite is not much modified, basal and prismatic sections being well shown, but it displays a tendency towards linear aggregation. Along the line of junction with the granite lies a band of biotite continuous across the slide. It is in part in contact with the vein, but in places it winds in and out amongst the hornblendes and felspars of the diorite. It is a sort of felt-work of small crystals, lath-shaped in section, averaging 0·25 millim. in breadth, lying with their longer axes in all directions. The dichroism is moderately strong. Similar mica and some epidote also appear in the adjacent granite, the former arranged with an imperfect approach to foliation. The granite consists of quartz and plagioclase, the latter very clear and well-twinned, both quartz and felspar being moulded upon or including the mica and epidote. There would appear to have been

* Quart. Journ. Geol. Soc. vol. xliii. p. 519.

mineral rearrangement in the granite, as well as in the diorite, arising out of the mutual interaction of the ingredients of the two kinds of rock.

The effects here described are very similar to those seen at Malvern. They are briefly the production in the diorite of (1) allotriomorphic hornblende, (2) chlorite and epidote, (3) black mica, especially when the rock has been compressed, (4) linear aggregation in the hornblende and mica.

5. *Mineral Aggregation and Enlargement.*

Aggregation as the result of contact-action was noticed by Mr. S. Allport * in 1876. The slate near the Land's-End granite is altered to mica-schist, and in places the quartz and the mica are aggregated into spheroidal and elliptical nodules. Prof. Bonney † states that in Brittany the granitic intrusions produce an enlargement of minerals in detrital rocks. Dr. Sorby and others have made similar observations. Both aggregation and enlargement are not unfrequent at the junction of granite-veins in the Malvern district. In a specimen (322, Pl. XVI. fig. 4) from Swinyard's Hill, in which a narrow vein of granite is enclosed in foliated black diorite, the hornblende is massed together at the junction in crystals, which are enormous compared with the average of size in this variety of diorite. One of them shows a prismatic section 6 millim. in length (the average length not exceeding 1 millim), and within it is enclosed a crystal of plagioclase. Similar effects may be seen in a biotite-gneiss north of the Wych. Even in hand-specimens, small granite-veins, 4 or 5 millim. thick, are surrounded by an aureole of black mica in large plates. Under the microscope (396) the large crystallization of the mica (Pl. XVI. fig. 5) is very well marked.

We have seen that aggregation is a common effect in gneiss-formation, the mica and the felspar of the kersantite respectively separating from each other and forming alternating bands, and the newly formed quartz coalescing into clusters of granules. How far the gneissic structure results from contact-action and how far from pressure will not be easy to determine.

6. *Introduction of new Minerals by Infiltration.*

The infiltration of the mineral which is now biotite is suggested by some of the preceding specimens (example, No. 277), but it is clearly shown in the following slides from a shear-zone situated a hundred yards or so to the south of the Wych. The first four are taken in the order of their occurrence, the extremes of the series being within one foot of each other.

No. 349. Medium black diorite with rough parallelism. Hornblende drawn out at shear-planes and somewhat corroded. Decomposition has commenced, some chlorite, epidote, and opacite

* Quart. Journ. Geol. Soc. vol. xxxii. p. 409.
† *Ibid.* vol. xliv. p. 15.

(iron-oxide?) being formed. The felspar contains a little white mica. Ilmenite and sphene are present.

No. 350. Idem. Crushing and decomposition carried further. Much opaque matter in the shear-planes. A great deal of chlorite in patches and parallel strings. Numerous microliths of a highly refracting mineral (sphene?).

No. 351. Granite crushed into a mass of wedge-like fragments. The principal cracks, which are roughly parallel, as well as numerous transverse fractures, are filled with minerals, of which chlorite and ferrite are by far the most abundant. Here and there in the chlorite are patches of biotite, which sometimes surround nuclei of ferrite. Microliths of the sphene (?) are also immersed in the chlorite.

No. 352. Granite partially transformed into gneiss. The slide is much clearer, apparently because of a certain amount of reconstruction. The wedges of felspar and quartz are much longer and thinner, and many of the cracks are healed up. There is still some chlorite in the cracks, with black mica and sphene (?) as before. I cannot resist the conclusion that the minerals in the cracks have been introduced from without, and that the biotite has been formed out of the chlorite. This rock passes *gradatim* into a thoroughly foliated gneiss (416).

That the chlorite and ferrite are not formed out of the granite is further evident from slides taken from the same junction of diorite and granite at a few feet from the last set. No. 409 is from the diorite close to the junction. The hornblende is decomposed mainly to epidote and chlorite, but the former is in exceptionally large proportion, occupying about one fourth of the slide. It is in small, brightly polarizing granules. Two slides (410, 411) are from the crushed granite within a few inches of the last. In No. 410 there are some small grains of similar epidote scattered here and there in the cracks; but in No. 411 the epidote is more abundant, filling in two cracks running parallel to the foliation, one of which opens out to the breadth of nearly 1·5 millim. In this vein the epidote is crystallized in prisms, sometimes with their pyramidal ends projecting into a water-clear mineral, apparently quartz, which has filled in the rest of the vein.

It is thus seen that where chlorite is most abundant in the decomposed diorite, chlorite is also the mineral predominating in the cracks of the adjacent granite, but that where epidote is most conspicuous in the former, it is also common in the latter. Irrespective of these coincidences, it is surely incredible that chlorite and epidote should be formed out of quartz and a potash-felspar.

This infiltration-gneiss forms the ridge for a hundred yards or so. Here and there we see in it lenticular flakes of granite, some of which are several inches thick. Sometimes they are elongated intc narrow cakes. At first sight they might be taken for veins; but I am persuaded they are merely residua from the shearing process, representing on a larger scale the flattened crystals of an augen-gneiss. It is not difficult to distinguish these residual flakes from

true veins. The latter in the Malvern district are always different in mineral composition from the encasing rock, but the flakes, allowing for their greater thickness, are mineralogically identical with the thinly sheared granite surrounding them. This gneiss differs, of course, from the variety produced by the simple shearing of granite by the presence of chlorite, biotite, and other minerals at the shear-planes.

II. Chemical Considerations.

The conversion of diorite into a highly quartzose or micaceous rock involves profound chemical changes. It will be well to trace the most important of these.

The *removal of bases* comes first in order. I have already alluded to the silicification, partial or complete, of granite-veins. The change is most marked in those of small size. Under the microscope the process of alteration becomes apparent. The felspar is seen to be invaded by quartz, which runs up into the crystals in streams broadening outwards like estuaries. This quartz is in granules, polarizing in a mosaic of colours. Sometimes the quartz appears dotted here and there in the felspar in single granules or small clusters of granules, but these are probably the transverse sections of the streams. There is also replacement by quartz in some of the felspar of the kersantite, the invasion of the quartz at the margin of the felspars giving to the latter a sinuate or dentate outline, and the corrosion often goes on till the crystal is destroyed. Perforation occurs also in the case of hornblende and black mica, so that crystals appear riddled with holes, and in some cases they are reduced to shreds. These corroded remnants are usually immersed in a translucent mineral, which is frequently quartz *.

A partial account may be given of the bases liberated by the separation of silica. The lime of both hornblende and soda-lime felspar appears in epidote, that of some of the felspar in zoisite, and that of some of the hornblende possibly in sphene ; but the abundance of free calcite in some of the more altered rocks shows that much of the lime must have percolated in solution through the crust as carbonate. The iron of the decomposed hornblende is readily accounted for by the epidote, chlorite, biotite, and ferrite. The magnesia reappears in chlorite and biotite. Alumina, of course, occurs in most of the above alteration-minerals, in the white mica, and the garnets.

The chemical energy resulting in the removal of the heavy bases must have been accompanied by the liberation of compounds of the alkalies. These, as carbonates or silicates, could readily have been carried in solution from place to place.

There has been *interchange of alkaline bases* between the acidic and the basic rocks. The Rev. J. H. Timins † stated more than 20

* The constituents of the granular rocks of Malvern are often too small for the determination of the axial characters.

† Quart. Journ. Geol. Soc. vol. xxi. p. 85.

years ago that the potash in the orthoclase of the Malvern granite had been partially replaced by soda. The following analyses by Mr. J. H. Player *, F.G.S., tend to confirm this statement. The alkalies only are here given :—

	Soda.	Potash.
A. "Quartz-felspar, Malvern, North Hill"	3·7	4·9
B. "Quartz-felspar, Malvern, coarse graphic texture"...	1·9	7·1
C. "Quartz-felspar, Malvern, red rock, fine-grained"...	2·6	4·0

This "quartz-felspar" is undoubtedly the ordinary granite of the district. The proportion of soda in (B) is about normal, but in the other two examples there has been a gain of soda and a loss of potash.

We have seen that in the vicinity of granite-veins, one of two changes is ordinarily seen in diorite, either chlorite is converted into black mica, or white mica appears in the place of soda-lime felspar †. Potash must therefore have been taken up. Two analyses of diorite, kindly furnished me in MS. by Mr. Player, confirm the evidence of the microscope. I am able to identify the varieties from slides sent by Mr. Player. D is a typical coarse grey diorite with plenty of hornblende. E is the medium black variety, and has undergone partial metamorphism, a narrow seam of biotite-gneiss running across the middle of the slide.

	Soda.	Potash.
D. "Diorite, Malvern, North Hill"	2·3	4·3
E. "Basic rock, Malvern"	2·2	3·9

The chemical processes described in this paper are in harmony with what is known of mineral changes. On the whole they illustrate a transition from the unstable to the stable. Stability is, of course, relative to environment, so that biotite in the presence of solutions of potash may be as stable as chlorite in their absence. The unstable minerals, hornblende, augite, potash-felspar, and soda-lime felspars, forming the bulk of the igneous rocks, are, in the schists, replaced by quartz and white mica, black mica, epidote, chlorite, garnets, actinolite, iron-oxides, calcite, and natrolite ‡. It seems probable that the only original minerals are apatite, hornblende, and augite, with part of the quartz, felspars, and iron-ores. The capital facts to be noted are the secondary origin of all the micas, the abundant generation of quartz, and the reconstruction of felspar.

III. Temperature of Metamorphism.

The facts adduced seem to prove that the metamorphism has to a large degree taken place in rocks already consolidated. Whether in granite or diorite the foliation is connected with a shearing-

* British Association Report, 1886.

† From the frequent appearance of untwinned felspar in diorite near granite-veins it would appear probable that plagioclase passes into muscovite through the intermediate form of orthoclase ; but further inquiry is needed.

‡ Rutley, Quart. Journ. Geol. Soc. vol. xliii. p. 501.

movement, by which minerals are distorted and broken, and rock in the mass is sliced by countless planes of infiltration. As Mr. Mellard Reade * contends, following M. Tresca, solid rock under enormous pressure is compelled to flow. In this case, the pressure must have been approximately horizontal, and, the flow being normal to the direction of pressure, the dips of the foliation are usually at very high angles.

But where we find an ordinary massive diorite with cloudy felspar, passing insensibly into a rock in which allotriomorphic hornblende, aggregated into seams, alternates with transparent clearly twinned felspar, which is completely moulded to the curvilinear margins of the modified hornblende, to the angles of cleavage-fragments of the same mineral, and to the contours of decomposition-products, such as chlorite and epidote, we are driven to conclude that the mechanical cause has operated in conjunction with an actual fusion or solution of some of the constituents. Or take the production of a sound gneiss out of a mass of crushed granite containing infiltrated decomposition-products. Much of the orthoclase is reconstructed in small crystals or in granules, secondary granular quartz is generated, most of the opaque matter in the cracks is chemically absorbed, and direct evidence of the crushing and shearing is obliterated. The cleanest, soundest schists generally form the bands of maximum shearing, and we are forced to infer a connexion between the degree of reconstruction and the degree of shearing. On the whole, it seems probable that the pressure generated sufficient heat to fuse or dissolve some of the rock in and near the sheared bands.

Solution appears more probable than fusion. The action of water is shown by the abundance of chlorite and calcite, and by the other decomposition-products which have been infiltrated into shear-planes and cracks in crystals. The most recent chemical researches prove that a very minute proportion of water will suffice to hold a silicate in solution. The comparative solubility of felspar is illustrated by the frequency of the occurrence of fragments of crushed hornblende-crystals as inclusions in clear plagioclase.

Whether the whole of the diorite and granite had consolidated before the chief mechanical force came into operation is not easy to determine, but an affirmative answer is probable. The granite is certainly younger than the diorites, yet in numerous cases examined the first stage in the conversion of the granite into gneiss is the crushing of the rigid rock into a mass of lenticular fragments. The Ragged-Stone-Hill felsite, too, which penetrates the coarse grey diorite (the younger of the two chief varieties), is sometimes sheared like a solid mass. If any parts of the Malvern complex had not consolidated before metamorphism, they were in a very small proportion.

The views to which the writer has been led by the study of the Malvern rocks agree in the main with the modern theories of dynamic metamorphism; but the chemical changes here recorded appear to be greater than any previously observed.

* Origin of Mountain-Ranges, p. 168.

Summary.

1. All the crystalline rocks of the Malvern Chain are of igneous origin.

2. The gneisses and schists are produced out of igneous rocks by secondary action.

3. The chief mineral and chemical changes have taken place in bands of rock (shear-zones) which have been subjected to a shearing-movement, so that the metamorphism may be described as "zonal." The maximum of alteration has been produced in diorite which has been sheared in proximity to granite-veins. Contact-effects are here combined with dynamic metamorphism.

4. The most important chemical changes are the removal of bases and the combination of potash with some of the constituents of diorite.

5. The chief mineral changes are the reconstruction of felspar, and the production of biotite (from chlorite), white mica (from orthoclase, plagioclase, black mica, and chlorite), granular quartz, sphene, and actinolite.

EXPLANATION OF PLATE XVI.

Figs. 1, 2, 3. Series showing the conversion of kersantite through mica-gneiss into gneissoid quartzite. (Shear-zone at Swinyard's Hill, p. 482.)

Fig. 1 (313, p. 485). Kersantite, being diorite (275, 276) altered at contact of granite-vein, which appears at the upper part of the slide. Some aggregation of the mica is seen at the junction.

2 (277, p. 486). Biotite-gneiss from the shear-zone. Structure similar to last, but more aggregation of the mica in continuous folia. Passing, in the same slide, insensibly, both transversely and longitudinally, into the gneissoid quartzite of fig. 3.

3 (277, p 486). Gneissoid quartzite. Most of the felspar has been replaced by quartz, and much of the mica has disappeared.

4 (322, p. 496). Diorite, with granite vein at the upper side. To show aggregation and enlargement of the hornblende at the contact.

5 (396, p. 496). Biotite-gneiss, with granite-vein. To show similar effects with mica.

6 (403, p. 480). One of the later slides of the diorite-series at the shear-zone at West Malvern. Along the line *a* . . . . *a* fragments of hornblende crystals are arranged in an irregular folium. In the upper square a cluster of biotite crystals is moulded on the hornblende. The line *b* . . . . *b* indicates the position of a band of biotite interlaminated with chlorite. In the lower square the biotite encloses a crystal of epidote. The rest of the slide is mainly white mica and epidote.

Discussion.

The President observed that the gist of the question lay in the evidence.

Mr. Rutley said that the Malvern Hills offer comparatively small and interrupted exposures of rock. He went there with no preconceived opinion, and concluded that a certain number of the rocks were eruptive, although he considered that a large proportion consisted of the detritus of eruptive rocks, while, towards the south

end they were mainly micaceous schists and bedded quartzites, which he regarded as altered sedimentary rocks. There is a difference too in the specific gravity of the minerals as we go from north to south, the percentage of those of higher density being greater in the northern parts of the range. There was nothing very remarkable in the biotite-gneisses of Swinyard's Hill. In cut sections he had not seen much evidence of mechanical deformation of eruptive rocks, although plenty of decomposition-products were present. The crushed material in the so-called shear-zone at West Malvern he regarded as possibly a friction-breccia. Some of these zones are, very likely, mere dislocations. There was no correspondence between the direction of the faults and the strike of the bedding and schistosity. He still adhered to his previous conclusions.

Mr. Teall confessed that his ideas on the general question were in an inchoate stage. He was much interested in the paper, and agreed with many of the points, but should require more detailed knowledge of the locality. With regard to shear-zones, he was somewhat of Mr. Rutley's opinion; he was not quite certain that he understood the Author. Foliation as evidence of shearing was the point under discussion; but the Author appeared to take it for granted. As evidence that the shearing motion has taken place, the Author describes the mechanical deformation of minerals; are they invariably found along the zones where foliation occurs? Many of the rocks do not show a trace of shearing of this kind. There was no evidence of this tearing asunder of the minerals. The main point is, How can we tell, when dealing with holocrystalline rock, whether the structure is original or superinduced, so far as microscopic evidence is concerned, and without reference to the results of field-work? As subsidiary points, there was the conversion of hornblende into black mica, but he was surprised to hear that this had been effected through the intervention of chlorite. He agreed that white micas had been derived from the felspars. He referred also to the development of granulitic aggregates of quartz in the place of felspar, and asked if the Author was sure that the grains were quartz and not felspar.

Dr. Hicks agreed with the Author to a certain extent, but he failed to see why the original minerals should remain unaltered or merely deformed so near the shear-zones, if the general metamorphism was produced by shearing. As to the granite-veins, are they really intrusions or, as is more probable, segregation-veins only? If so, this would show that the greatest amount of change in these rocks is due to secondary deposition along lines of weakness.

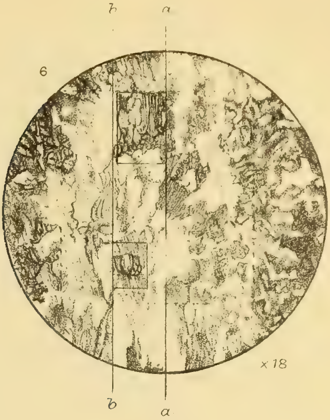
Prof. Blake was glad to hear that Mr. Teall admitted the existence of schists in which there was no evidence of shearing. What might be the origin of these parallel structures was quite a different question from that of the production of sheared rocks. In the case of the latter the amount and direction of the motion that had taken place was directly ascertainable by an examination of the position of the fragments of the deformed crystals.

Quart. Journ. Geol. Soc. Vol. XLV. Pl. XVI.

1

x 18

6



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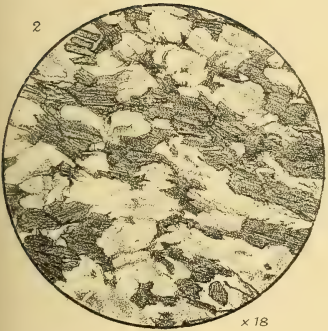
2



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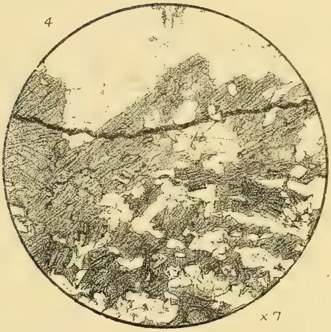

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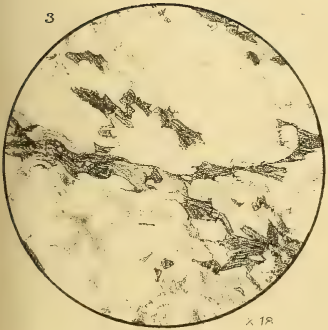
3



x 18

5

x 7

West, Newman lith.

ROCKS FROM THE MALVERN CHAIN.

Dr. Irving alluded to the important difference presented by the phenomena of the shear-zones and those of the masses of the gneisses. We have no right to assume that these rocks are metamorphic in their origin. The question of the replacement of bases is one of much interest. He explained how potash may be replaced, and gave illustrations: there would be variations in the results according to the quantity of free carbonic acid acting on the silicates.

The Author, in reply, stated that he had not raised the general question as to the origin of the crystalline schists. Mr. Rutley recognized sedimentary rocks towards the south end of the chain. This appearance was simply due to more intense shearing. The rocks were more highly quartzose, the result of more intense metamorphism. The crushed rock gradually passes into the reconstructed rock. He allowed that black mica may be derived directly from hornblende, but that was not the case in the Malvern Hills. He dissented from the notion of friction-breccia. Mr. Teall's point was the kernel of the whole question. There was deformation at the margins of the zones, but not in the centre, because the rock had been reconstructed; eyes of felspar are often seen in the most highly foliated rocks. A granular structure was characteristic of the reconstructed bands. There was no distinction between smaller and larger granite-veins. He referred to Prof. Blake's point as to the evidence of shearing in the broken hornblende crystals. Most of the questions raised were answered in the paper.

31. OBSERVATIONS *on some* UNDESCRIBED LACUSTRINE DEPOSITS *at* SAINT CROSS, SOUTH ELMHAM, *in* SUFFOLK. By CHARLES CANDLER, Esq. (Read June 5, 1889.)

(Communicated by CLEMENT REID, Esq., F.G.S.)

THE well-known freshwater beds of Hoxne in Suffolk have attracted so much attention that a short account of some closely related deposits which I have recently met with in the same district will not, I hope, be without interest to students of our Pleistocene formations*.

The beds in question are situated in the parish of Saint Cross †, South Elmham, in the basin of the River Waveney, 3¾ miles E. by N. of the town of Harleston, and 9 miles E.N.E. of Hoxne ‡. The road from Homersfield Bridge to Halesworth, after first skirting and then crossing the terrace of gravel which here flanks the river on the Suffolk side, leaves the valley and enters the parish of Saint Cross, on the verge of the plateau of Chalky Boulder-clay which covers with a thick cap the district locally known as "High Suffolk."

The parish is intersected by the "South Elmham Beck," which has scoured a channel through the Boulder-clay deep into the underlying sands of the Middle Drift. Just beyond the village street the Halesworth Road crosses a broad and shallow trough, which a few yards lower down converges with the valley of the Beck. On the eastern slope of this lateral depression is a brickyard, and it is here that the beds to be described are exposed. On the same spot the Boulder-clay was for some time excavated, and this may perhaps account for the fact that the more recent formations have hitherto escaped notice.

At the top of the slope, on the eastern side of the brickyard, there is now an open section running at right angles to the road, and about 250 feet in length. The face of the section shows beneath a capping of surface soil and gravel a deposit of brickearth or loam. This bed thins out towards the north end of the line, where it may be seen resting upon the Boulder-clay, which here comes to the surface. The brickearth varies in consistence from a fine and stiff to a coarse and sandy or calcareous loam, and in colour from red to white. Angular yellow flints are common in the deposit. Its stratification is confused and sometimes scarcely discernible. There are in places indications of a double series, a red clay overlying a

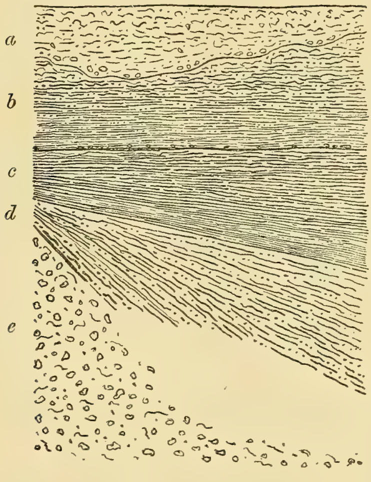
* I must express my great obligations to Mr. Clement Reid, F.G.S., at whose suggestion I have prepared these notes, for the help he has kindly given me in the work; and in particular for the list of plants accompanying this paper, the result of a careful examination by him of a quantity of material.

† Some confusion exists as to the name of this parish, which upon the Ordnance Map, and in all old records, is described as "Sancroft" or "Sandcroft," of which "Saint Cross" appears to be a modern corruption. The village is now, however, always known by the latter name.

‡ Quarter-Sheet 50 N.E. of the Ordnance Survey.

white; but the line of separation is very indefinite. The surface of the deposit where it meets the superjacent gravel and top-soil is deeply undulated, and it rests unconformably upon the bed below, the junction-line being straight and strongly marked. Beneath the brickearth there is a level floor of fine tenacious clay of a grey or blue tint, in places stained orange and red, and seamed near the base with partings of dark sand or loam. Towards the south end of the section, this clay gives place to, or is obscured by, a succession of mounds of loosely compacted silt or fine shingle, full of small rounded pebbles of chalk. Underlying the clay is a thick bed of black peaty loam, in places sandy, but generally stiff and wet, and smelling as strongly of decaying organisms as the mud of a marsh-

Diagram-section in Saint-Cross Brickyard.
(Scale 8 feet to 1 inch.)



		feet.
a.	Surface-soil and gravel	1 to 3
b.	Red and white loam; variable; fine or coarse; sandy or calcareous. Elephant, horse, &c. at base of bed....................................	3 to 5
c.	Fine tenacious grey and red clay, with carbonaceous seams towards the base. *Valvata, Bythinia, Pisidium*	2 to 5
d.	Black, peaty loam and sand worked to a depth of 5 feet, but no bottom reached. Seeds and freshwater shells	5
e.	Chalky Boulder-clay.	

drain. The surface of this lower bed, particularly in the southern portion of the section, is very uneven, sometimes swelling up in bosses, and sometimes sinking in deeply scooped hollows. Near the north-east corner of the brickyard the verge of the black bed has

been penetrated and the Boulder-clay below reached, but in the centre of the section I have not yet been able, owing to the water-logged condition of the deposit, to ascertain its depth; nor have I yet the means of estimating the superficial area of these freshwater beds. The brickyard is bounded on the south by the highroad, beyond which Mr. Aldous, the tenant of the property—to whom I am much indebted for the help he has given me—has made some small excavations by way of experiment; and he says that the loam extends at least 300 yards to the south of the present workings, and that he has also found traces of it on the opposite side of the little brickyard stream.

For convenience of reference, I have tabulated the beds as shown on p. 505, though the whole series is nowhere exposed in actual section.

As excavation is in active progress, the face of the pit varies, and varies considerably, from week to week, and it is impossible to give a measured section, the details of which will stand good for more than a few days. I have, however, indicated above, I believe with some approach to accuracy, the general succession of the beds.

The list of fossils obtained from the Saint-Cross deposits is as yet very imperfect, and will no doubt be largely added to when the formation has been more carefully studied. The base of bed *b* has yielded some teeth and a great number of fragments and splinters of bones and horns, a selection of which Mr. E. T. Newton has kindly looked through and determined the following species *:—

Elephas (*primigenius*?). 2 lumbar vertebræ and some fragments of limb-bones.

Equus caballus. 4 teeth.

Bos taurus, var. *primigenius*. Upper portion of tibia.

Cervus, sp. Teeth and fragments of bones and horns in great plenty.

In addition to the above, I have the greater part of the vertebral column of a fish, which I have not yet been able to identify, but which is probably a pike.

Bed *c* contains root-fibres and bone-fragments, but the latter are so disintegrated that it is very difficult to remove and impossible to identify them. The same bed contains the following shells :—

Bythinia tentaculata and *Valvata piscinalis*, both of which range through the whole series, and are in places extremely abundant.

Pisidium amnicum.

Mr. Clement Reid has washed and examined about 40 pounds of material from the lowest attainable portion of bed *d*, and has detected seeds of the following plants, with two exceptions all marsh or aquatic species :—

* I cannot, unfortunately, speak with certainty as to the exact position in which all these bones were found, as they had, many of them, been taken from the matrix some time before I saw them.

Thalictrum flavum, *L.*
Ranunculus aquatilis, *L.*
—— sceleratus, *L.*
—— flammula, *L.*
Cratægus oxyacantha, *L.**
Myriophyllum spicatum, *L.*
Hippuris vulgaris, *L.*
Hydrocotyle vulgaris, *L.*
Œnanthe phellandrium, *Lam.* (very small).
Cnicus palustris, *Hoffm.*? (badly preserved).
Taraxacum officinale, *Web.*
Menyanthes trifoliata, *L.*
Lycopus europæus, *L.*
Rumex maritimus, *L.*
Alnus glutinosa, *L.*
Ceratophyllum demersum, *L.*
Alisma plantago, *L.*
Potamogeton heterophyllus, *Schreb.*
—— perfoliatus, *L.*
—— crispus, *L.*
—— obtusifolius, *Mert. & Koch.*
—— trichoides, *Cham.*
Zannichellia palustris, *L.*
Scirpus pauciflorus, *Lightf.*
—— cæspitosus, *L.*
—— fluitans, *L.*
—— lacustris, *L.*
Carex riparia, *Curtis.*
—— rostrata, *Stokes.*

From the same sample Mr. Reid obtained two mosses, which Mr. Mitton has declared to be :—

Brachythecium plumosum †.
Amblystegium fluitans.

And also the following Mollusca :—

Limnæa stagnalis, *L.*
Valvata piscinalis, *Müll.*
Bythinia tentaculata, *L.*
Pisidium amnicum ?, *Müll.* (a fragment).
—— fontinale, *Drap.*
Sphærium corneum, *L.*

Some minute teeth and bones of vertebrates were also found, which Mr. Newton has verified as :—

Arvicola, sp. (vole).
Leuciscus rutilus (roach).
Tinca vulgaris (tench).
Esox lucius (pike).

The same stratum contains abundance of wood, and some time ago the trunk and main branches of a forest tree (Mr. Aldous says an oak) were found imbedded in the loam.

No palæolithic implements were found at Saint Cross, though flint flakes and chippings, more or less suggestive of human agency, are common in bed *b*. On a recent visit to the brickyard a workman gave me a small cast bronze or copper adze, which he had obtained some years ago from bed *c*, into which possibly it had fallen from the surface of the section ‡. I may mention here that when the present series of excavations at Saint Cross was begun, it was found that the brickyard had been tenanted before by an older generation of workmen. A kiln filled with wood-ashes, and of a long obsolete pattern, which had been completely buried and grassed over, was dug out, and a quantity of abandoned brickearth washed and utilized.

* Mr. Reid seems to have found no trace of the hawthorn in any of the postglacial deposits he had previously examined. See his "Notes on the Geological History of the Recent Flora of Britain," Annals of Botany, vol. ii. no. 6, August 1888.

† This species does not appear in the Rev. E. N. Bloomfield's list of the mosses of Suffolk—'Journal of Botany,' August 1885 and March 1888. It is usually found *in Subalpine districts* growing upon rocks and stones in damp places (Berkeley).

‡ The Rev. C. R. Manning, F.S.A., informs me that this implement is the blade of a socketed celt, broken off at the base of the socket, of the common type described by Dr. Evans in Chap. V. of his 'Ancient Bronze Implements.'

Although we have no means as yet of exactly correlating the Saint-Cross beds with those at Hoxne, it would not, I think, be well to close these notes without some further reference to the latter deposits. For purposes of ready comparison, I give one of Professor Prestwich's sections as quoted by Messrs. C. Reid and H. N. Ridley in an interesting paper read at the Bath meeting of the British Association in September last *.

Section in S.W. corner of Hoxne Brickfield, 1859.

	feet.
a. Surface soil, traces of sand and gravel	1 to 2
b. Brown and greyish clay, not calcareous, with an irregular central carbonaceous or peaty seam. Two flint implements. Bones of *Bos*	10 to 12
c. Yellow subangular flint-gravel, with a certain proportion of small chalk pebbles, and a few pebbles of siliceous sandstone, quartz, and other old rocks. *Elephas.* The matrix of this bed in places consists of clay like *b*	½ to 1
d. Bluish and grey calcareous clay, in places very peaty; lower part with seams or partings of sand. Wood and vegetable remains. Land and freshwater shells. Bones of Mammalia (deer, horse, and elephant)	3 to 4
e. Gravel like *c*, but smaller, more worn, and with more chalk pebbles	1 to 2½
f. Calcareous grey clay, more or less peaty, with freshwater shells (bored to 17 feet, but no bottom was reached)	17

On comparing this section with the description of the Saint-Cross beds, it will be seen that in lithological character, if not in order of sequence, there is a strong general resemblance between the two series. Indeed, I believe that no one who is familiar with the Hoxne sections, and who will examine the beds at Saint Cross, will fail to conclude that both the deposits were formed under very similar, if not identical, conditions. In comparing the fossil contents of the two formations one with another there is, with one exception, little to call for remark. A greater number of species have certainly been found at Hoxne than at Saint Cross; but this is only natural, seeing that the one deposit has been known for nearly a century, the other for scarcely a year. Messrs. Reid and Ridley, in their paper already referred to, give a list of 38 plants found by them in bed *d* of the Hoxne section, including *Betula nana*, *Salix polaris*, *S. Myrsinites*, and the alpine moss *Acroceratium sarmentosum*. On placing this list side by side with that of the plants found in bed *d* at Saint Cross, it will at once be noticed that the group of northern and arctic species is missing from the latter. But it must be remembered that Messrs. Reid and Ridley determined the northern birch and willows from *leaves* which they found in finely bedded clay, possessing far higher preserving powers than the Saint-Cross bed *d*. Until we meet at Saint Cross with a

* "Fossil Arctic Plants from the Lacustrine Deposit at Hoxne in Suffolk." By Clement Reid, F.G.S., and H. N. Ridley, M.A., F.L.S.—Geological Magazine, Decade iii. vol. v. no. 10, p. 441 (October 1888).

stratum capable of preserving such leaves, but which does not contain them, we must not attach too much significance to their absence. On the other hand, the presence of a large tree in the upper portion of bed *d* at Saint Cross, considered with the absence of northern plants, suggests the prevalence of a much less rigorous climate than that under which the leaf-bearing beds at Hoxne were deposited. Indeed, some of the plants found at Saint Cross do not range much further north at the present day, and with two or three exceptions the whole of them are now living in the immediate vicinity. It is possible, therefore, that the Saint-Cross bed *d* may be synchronous with the lowest bed (*f*) of the Hoxne section, the leaf-bearing bed above marking the recurrence of another cold period, corresponding perhaps with the advance of an ice-sheet over the northern counties.

An important point to be considered with reference to these formations is their connexion, if any, with the present drainage system of the country. So far as the Saint-Cross beds are concerned, there is little in their position to show that any such connexion exists. They now occupy a ridge or tongue of land between two depressions, from both of which they may have been in part denuded, and on the crest of this ridge they appear to attain their greatest depth. Moreover, the deposits terminate on the very verge of the valley of the South Elmham Beck, high above the present level of the stream, the sands of the Middle Glacial Drift being exposed below the brickyard in a pit at the base of the valley slope. The greater part of the valley has been eroded since the formation of the lacustrine beds, and it is at least doubtful whether during that period the stream had any existence at all. The watercourse which now drains the brickyard may, however, indicate the direction in which the surplus waters of the old lake were discharged.

It appears probable that on the final retreat of the last ice-sheet which invaded these counties, the hollows of the Boulder-clay were occupied by a series of lakes and pools. For the most part the sedimentary deposits formed in these hollows have been entirely swept away. But at Saint Cross the mud and loam of one such lake, the position of which has protected them from erosion, have resisted the agencies which have completed elsewhere the work of obliteration. The flora of the bed *d* proves that Arctic conditions had given place to a more temperate climate when that deposit was thrown down, and this implies the lapse of a considerable interval since the formation of the Chalky Boulder-clay. A long period of time must, however, have been required for the accumulation of the whole series. Bed *d* points to the existence of a shallow, weed-grown pool with marshy shores and islets, filling a hollow in a wooded and undulating country. After this, an increasing depth of water checked the growth of vegetation, and the clays of bed *c* were deposited by the waters of an undisturbed lake. The junction of beds *c* and *b* evidently marks a change of conditions, and, if the root-fibres in the clay are those of land-plants, the escape or evaporation of the waters of the lake and the intervention of a

dry surface. Finally, the brickearth of bed *b*, containing abundance of stones and very few organic remains, suggests a period of floods and turbid waters, with a correspondingly rapid denudation of the surrounding area.

Discussion.

The Chairman spoke of the interest of these beds in connexion with those of Hoxne. Mr. Clement Reid had supplied the material for a comparison of the floras from the two localities.

Mr. Clement Reid had little to add to the paper; he was glad to know that a resident had undertaken to work a country which, as a rule, was carefully avoided by all geologists. From the resemblance to the deposits at Hoxne he had expected an Arctic flora, but the plants were such as now live in Norfolk and Suffolk, having also a wide N. and S. range. This was the first case of the hawthorn occurring as fossil in Britain. The lacustrine deposits of Hoxne and St. Cross may form a series linking on the glacial beds with those of the present day. He agreed with the Author that the lakes probably occupied hollows left in the Boulder-clay on the retreat of the ice.

Prof. Prestwich referred to the important addition to the flora, and spoke of Mr. Clement Reid's method as having thrown great light on the subject within the last few years. Previously little was known of the flora of these mammaliferous beds.

Mr. Lydekker wanted to know how *Bos primigenius* was to be distinguished from *Bos taurus* by the teeth alone.

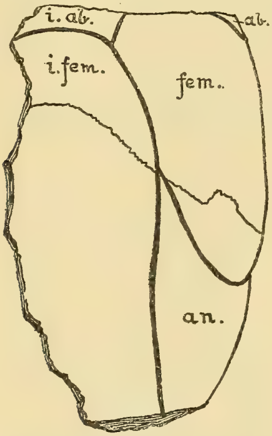
32. *On certain* Chelonian Remains *from the* Wealden *and* Purbeck.

By R. Lydekker, Esq., F.G.S., F.Z.S., &c. (Read June 5, 1889.)

a. *Plastron from the Wealden.*

Certain fragments of the plastron of a Chelonian collected by the late Dr. Mantell from the Wealden of Sussex, and now preserved in the British Museum, are of some interest as affording evidence of the presence of an additional series of epidermal shields unknown in any previously described form, and probably indicating an extremely archaic type of structure.

Fig. 1.—*Left hypo- and xiphiplastral of a Chelonian; from the Wealden of Cuckfield.* ($\frac{2}{3}$ nat. size.)



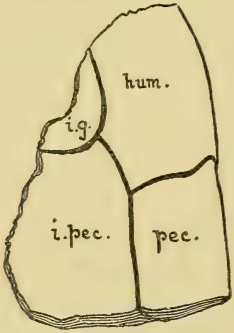
ab., abdominal shield; *fem.*, femoral do.; *an.*, anal do.; *i.ab.*, interabdominal do.; *i.fem.*, interfemoral do.

The first specimen that may be noticed is the imperfect left xiphiplastral, to which is suturally united a portion of the hypoplastral, this bone (No. 3506) being represented in fig. 1. It appears probable that the proximal portion of the bone is broken away, and that the hypoplastral element was originally extended upwards to form the inguinal portion of the bridge for connexion with the carapace. The peculiar features connected with this specimen are, however, the sulci left by the epidermal shields. It will be seen from the figure that on the outer border there are two narrow shields (*an.*, *fem.*) which from their relation to the xiphiplastral suture I take to represent the anal and femoral shields of

the normal type. Above the femoral is seen the commencement of a third lateral shield, which may be correlated with the abdominal. On the inner side of these lateral shields are portions of two larger shields, which may be termed interfemoral and interabdominal. There are no means of determining whether these inner shields were azygous or paired, although I am inclined to think that they were probably azygous. On the dorsal surface of the specimen the absence of any pelvic attachment to the xiphiplastral indicates that the Chelonian under consideration was allied to the Cryptodiran section.

The next specimens are two examples of bones which are provisionally regarded as left hyoplastrals, one of which (No. 3532) is represented in fig. 2, while the other (No. 3533) is figured in Mantell's 'Fossils of Tilgate Forest,' pl. vii. fig. 3. Anteriorly they exhibit surfaces which are assumed to be for the articulation of the epi- and entoplastrals; while posteriorly there is an entire natural surface which appears to have articulated with a mesoplastral element, since, if these bones be rightly determined, it is quite evident that they took no part in the formation of the axillary portion of the bridge. I conclude, therefore, that the structure of the plastron

Fig. 2.—*Left Hyoplastral* (?) *of a Chelonian; from the Wealden of Cuckfield.* ($\frac{2}{3}$ nat. size.)



i.g., intergular shield; *hum.*, humeral do.; *pec.*, pectoral do.; *i.pec.*, interpectoral do.

was probably of the same general type as in *Sternothærus*, where the hypoplastral forms the inguinal, and the mesoplastral the axillary half of the bridge. The whole plastron must, however, have been much longer and narrower than in that genus, in which respect *Chelodina* makes the nearest approach among existing types. Both specimens exhibit an inner and an outer row of epidermal shields, which affords the ground of reference to the same form as the preceding specimen. The two outer shields I correlate with the humeral and pectoral; while the uppermost of the inner row appears to represent the intergular of *Chelodina*, and the lower

one may be named interpectoral. On this view the gulars will have been placed anteriorly to the intergular in the same manner as in *Chelodina*.

Our specimens indicate, therefore, a Chelonian of medium size, characterized by the occurrence of a row of median, and probably azygos, plastral shields, dividing the normal plastral shields below the gulars. This series is a continuation of the intergular now found in all *Pleurodira* and some *Cryptodira*, and may in all probability be regarded as indicating an archaic type of structure, the Chelonian plastron having probably been developed from abdominal ribs like those of *Sphenodon*, and apparently showing a tendency to the obliteration of some of its elements with advancing specialization. No existing Chelonian exhibits this multiplication of plastral shields; but Mr. Boulenger has figured a minute interanal shield in two specimens of *Macroclemmys*, one of which also exhibits an equally minute azygos shield in the centre of the plastron.

A feature of a somewhat analogous nature to that characterizing the plastron under consideration is, however, found in the carapace of a Chelonian from the Kimeridgian of Hanover, figured by Dr. Portis in the 'Palæontographica,' vol. xxv. pl. xv., under the name of *Tropidemys Seebachi*. In that specimen the normal azygous series of vertebral shields is divided into two lateral series by a more numerous row of small intervertebral shields, nearly corresponding in number with the underlying neural bones. In the characters of the bony elements of the carapace that specimen corresponds closely with typical species of *Tropidemys*; but the multiplication of the shields should not improbably be regarded as a generic character. It occurs to me that the carapace of the Wealden form may perhaps have had a similar series of intervertebral shields.

b. *The Affinities of* Pleurosternum.

The Purbeck Chelonian to which Sir R. Owen applied the name *Pleurosternum latiscutatum*, as has been shown by Mr. Boulenger and myself, has no connexion with the Pleurosternidæ *, but belongs to the Plesiochelyidæ; and from the evidence afforded by a nearly entire shell of the last-named species from the Wealden, it appears that the plastra described by Sir R. Owen as *Platemys Mantelli* and *P. Dixoni* are really referable to the so-called *Chelone Belli*, which is thus shown to be an allied form.

It may also be observed in this connexion that the so-called *Pleurosternum latiscutatum* was provisionally referred by my friend and myself in the paper above cited to the genus *Plesiochelys*. Subsequent observations have, however, shown that the vertebral shields are much wider than in that genus; and since there are other distinctive features which I shall indicate elsewhere, I feel justified in proposing the new generic name *Hylæochelys* for this Chelonian. I may state, however, that I have found it impossible

* Geol. Mag. decade 3, vol. iv. p. 272 (1887). In this communication *Pleurosternum* was referred to the Pelomedusidæ.

to satisfy myself absolutely that this form is generically distinct from either *Hydropelta* of the Lithographic Limestone or *Chitracephalus* of the Wealden, the type specimens of those two genera being of a character which does not admit of exact comparison. I shall, however, elsewhere adduce certain evidence tending to show that *Hylæochelys* is not identical with *Chitracephalus*. A second species of *Hylæochelys* will be represented by *Chelone Belli*, which appears to be specifically distinct from the type species; and in any case the specific name *Belli*, as the earlier, has a right to stand. The Chelonian from the Kimeridgian of Hanover described by Maack * as *Chelonides Wittei* would appear to indicate a form more or less closely allied to *Hylæochelys*; but the generic name is preoccupied †. The insufficiently described *Plastremys*, Owen, is probably also identical with this genus.

Reverting to the forms described as *Pleurosternum*, it is evident that the type of *P. emarginatum*, Owen, also belongs to *Hylæochelys*, although the other examples referred to that species by its founder are veritable Pleurosternidæ. Again the specimen from the Wealden of Germany described as *P. Kœneni* ‡ is likewise referable to the new genus, and probably belongs to the type species.

The removal of these three species from *Pleurosternum* will reduce the four species assigned to that genus by its founder, Sir R. Owen §, to two, viz. *P. concinnum* and *P. ovatum*. The former species is the first of the four which are referred to the genus in the original memoir, and, as pointed out by Prof. Cope ‖, must undoubtedly be regarded as the type of the genus. In the joint communication by Mr. Boulenger and myself published in the 'Geological Magazine,' to which reference has been already made, it was shown that the plastron described by Sir R. Owen at an earlier date under the name of *Platemys Bullocki*, and erroneously supposed to have been obtained from the London Clay, was in reality from the Purbeck, and appeared to be specifically identical with the type of *Pleurosternum ovatum* and with some of the specimens described as *P. emarginatum*. We accordingly proposed to supersede the name *Pleurosternum ovatum* by *Pleurosternum Bullocki*, making no mention of *P. concinnum*. It had, however, escaped our notice that Prof. Cope ¶ had seen occasion to regard the so-called *Platemys Bullocki* as generically distinct from *Pleurosternum* (typified by *P. concinnum*), and had proposed for it the name *Digerrhum*.

It appears, indeed, so far as I can gather, that Prof. Cope was induced to separate *Platemys Bullocki* from *Pleurosternum* on the ground that the latter had no intergular shield. A portion of such shield is, however, clearly seen in *P. concinnum*—the type of the latter genus—and the distinction consequently falls to the ground.

* 'Palæontographica,' vol. xviii. part 2, p. 133 (1869).
† In 1834 for a genus of Lepidoptera.
‡ Grabbe, 'Zeitschr. deutsch. geol. Ges.' vol. xxxvi. p. 19 (1884).
§ 'Wealden and Purbeck Reptilia' (Mon. Pal. Soc.), pt. i. p. 2 (1853).
‖ Geol. Mag. decade 3, vol. iv. p. 573 (1887).
¶ Trans. Amer. Phil. Soc. vol. xiv. pt. i. p. 156 (1870).

At one time I thought that the undermentioned specimens might on other grounds justify the retention of *Digerrhum* as a form closely allied to *Pleurosternum*, but further consideration induced me to regard all the above-mentioned forms as referable to one genus, and probably to a single species, for which the name *Pleurosternum Bullocki* should be adopted.

It may be added that while *Pleurosternum* was, from the assumed absence of the intergular, referred by Prof. Cope to the Cryptodira as the type of a family, *Digerrhum* was classed among the Pleurodira in the existing family Sternothæridæ, which is included by Mr. Boulenger among the Pelomedusidæ.

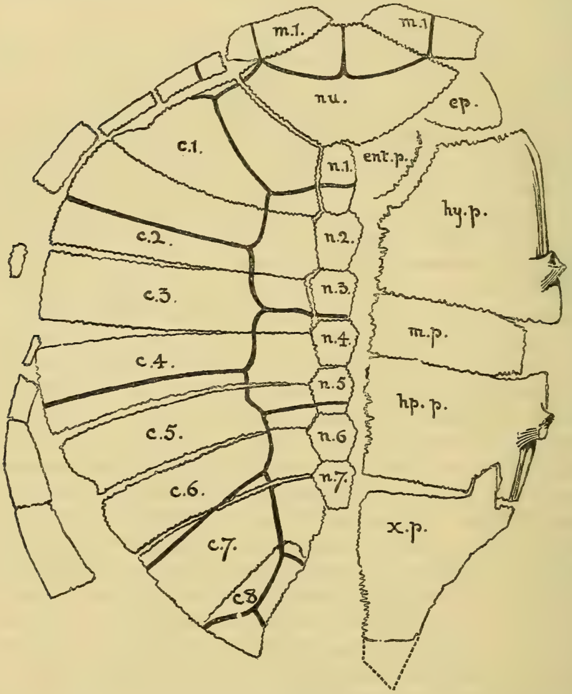
Having now cleared the ground, we may proceed to consider the specimens which I have to bring to notice as affording evidence of the affinities of *Pleurosternum*. It may be observed in the first place that the most distinctive feature of this genus is the presence of a complete mesoplastral element in the plastron (fig. 3), this feature occurring elsewhere, so far as is known, only in the allied *Helochelys* of the Neocomian, in the existing Pleurodiran genus *Sternothœrus*, and possibly in the Triassic *Proganochelys*; while such an element, although of a different type, is considered to have been probably developed in the Wealden form described in the first part of this communication.

Further the shell is comparatively smooth, and has an intergular but no nuchal epidermal shield; while the entoplastral is wide and of relatively large size. There is, moreover, a full series of neural bones, of which the 8th articulates with the 1st suprapygal; while the vertebral shields are relatively wide.

The first of the two specimens I have to bring under the notice of the Society is a small slab of rock (B.M. No. 48262), showing the greater part of the flattened shell of an immature Chelonian. This specimen, which is represented of two thirds the natural size in fig. 3, shows the greater part of the median line and of the left half of the carapace, the right half of the latter having been chiselled away in order to exhibit the dorsal surface of the plastron. The general contour of the specimen, the absence of the nuchal shield, and more especially the complete mesoplastral bones, at once indicate that it belongs to the Pleurosternidæ. It will be seen from the figure that the first marginal bone of either side encroaches so largely on the anterior border of the nuchal, as to leave scarcely any free border to that bone; and I was at first inclined to consider this a specific distinction from *Pleurosternum Bullocki*. Finding, however, that the same feature occurs in another young carapace (and, indeed, in all the young specimens in the Museum), while all the adult specimens show a more normal type of nuchal, I have finally come to the conclusion that the feature obtaining in the nuchal of the specimen under consideration should probably be regarded as characteristic of immaturity. It should, however, be observed that in Sir R. Owen's figure of the type specimen of *P. concinnum*, the first marginals appear to have a somewhat similar relation to the nuchal as obtains in the present young specimen; but an inspection of the

figure shows that there is some confusion between bony sutures and the sulci formed by horny shields, so that it is quite possible the figure may be incorrect in this respect. And even if correct, I should be disposed to regard this feature merely as an individual abnormality, seeing that the associated plastron presents no characters by which it can be specifically distinguished from that of *P. Bullocki*,

Fig. 3.—*The imperfect Shell of an immature individual of* Pleurosternum Bullocki; *from the Purbeck of Swanage.* ($\frac{2}{3}$ nat. size.) (B. M. No. 48262).



The costals of the right side have been removed in order to exhibit the dorsal aspect of the plastron.

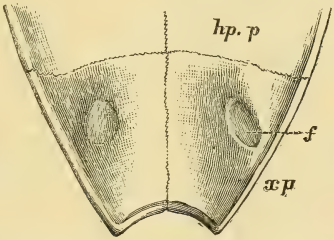
m. 1, first marginal bones; *nu.*, nuchal; *n.* 1–*n.* 7, neurals; *c.* 1–*c.* 8, costals; *ep.*, epiplastral; *ent.p.*, entoplastral; *hy.p.*, hyoplastral; *m.p.*, mesoplastral; *hp.p.*, hypoplastral; *x.p.*, xiphiplastral.

and bearing in mind that if this feature be regarded as specific, we should have to refer all the young specimens to *P. concinnum*, and all the adult specimens (except the solitary type of the latter) to *P. Bullocki*. I accordingly regard the specimen represented in fig. 3 as probably belonging to a young individual of the latter and only definable Purbeck species of the genus. The importance of this specimen is that it shows the absence of any connexion between the

bones of the pelvis and the plastron. This specimen differs from adult examples of *P. Bullocki* not only in the above-mentioned point, but also in the relatively wider vertebral and costal shields, and the circumstance that the first marginal bone articulates wholly with the nuchal instead of largely with the first costal; while, as shown by other specimens, the mesoplastral terminates outwardly in a point. All these features must apparently be regarded as characteristic of the young.

The second specimen (B.M. No. R. 1524) is a portion of an adult plastron, which shows both the dorsal and ventral surfaces of the bone. It agrees in all respects with other specimens of the plastron of *P. Bullocki*, and there can be no hesitation in referring it to that species.

Fig. 4.—*Dorsal Aspect of the Posterior Extremity of the Plastron of* Pleurosternum Bullocki ; *from the Purbeck of Dorsetshire.* ($\frac{1}{3}$ nat. size.)



hp.p., hypoplastral; *xp.*, xiphiplastral; *f.*, facet for pubis.

The peculiar feature of this specimen (fig. 4) is the presence on the dorsal aspect of the xiphiplastral of a facet (*f*), for the articulation of the pubis. This facet occupies precisely the same position as in the plastron of the Jurassic Pleurodiran genus *Plesiochelys*, where only the pubis unites with the plastron; and also corresponds to the pubic articulation in existing Pleurodirans, where both pubis and ischium unite with the xiphiplastral. Whereas, however, in true Pleurodira, the union between the pelvis and plastron is a sutural one, in the present instance these bones appear merely to have articulated by smooth facets.

If I am right in referring these two types of pelvis to a single species (and in any case they indicate extremely nearly allied forms which cannot be generically separated), it would appear that while the young of *Pleurosternum* had a type of pelvic structure similar to that which obtains in the Cryptodira, the adult approximated to the Pleurodiran modification. This being so, it remains to consider whether we are to regard these Chelonians as Cryptodirans approximating to the Pleurodira, or as very generalized Pleurodirans, or as the representatives of a section distinct from both.

This, I admit, is a question of some difficulty; but since it is practically certain, as M. Dollo has pointed out, that we must regard both the Cryptodira and Pleurodira as divergent branches from an original

common stock, it is quite evident that such stock must have had a plastron of very much the type of that of the Pleurosternidæ; that is to say there must have been a mesoplastral bone and an intergular shield, since these features, if once lost, would be very unlikely to reappear. Further, we should expect such an ancestral type to show such differences in the relation of the pelvis to the plastron as we find obtaining in the specimens before us. If we refer the Pleurosternidæ to the Cryptodira, we should destroy the definition of that section by the inclusion of a form with a union between the pelvis and the plastron; while if we assign them to the Pleurodira, we should equally invalidate the definition of that group, since we should have to include a genus with a free pelvis in the young.

Under these circumstances, it appears to be the preferable course to regard this family as the representative of a generalized section, of which the earlier (unknown) members were the common ancestors of the Cryptodira and Pleurodira; and I accordingly propose for this section the name of Amphichelydia.

The Neocomian genus *Helochelys* will certainly come in the Pleurosternidæ; while I think the Baënidæ of Prof. Cope, as represented by the Upper Jurassic *Platychelys* and the Eocene *Baëna*, may probably be likewise included in the same family, and will certainly come in the same section. Prof. Cope has, indeed, remarked on the peculiarly generalized affinities of *Baëna*, which he regards as exhibiting decided evidence of affinity with the Pleurodira, especially in the approximation towards a union between the pelvis and the plastron.

The Amphichelydia, as thus exemplified, will include all those forms hitherto referred to the Cryptodira which possess a mesoplastral bone, and will thus enable us to add to the definition of that section the absence of this bone.

Finally, I may observe that the pectoral girdle and humerus of *Pleurosternum* are of a decidedly Pleurodiran type, coming near to those of the existing *Chelys*. I have, indeed, studiously avoided all reference to the structure of the skull and neck, which affords such an important distinction between the existing members of the Cryptodira and Pleurodira, since it will be quite evident that any evidence adduced from them can have no possible bearing in a case where their structure is totally unknown.

Discussion.

The Chairman said that some interesting points of difference between the living and extinct forms of Chelonia had been well brought out by the Author.

Prof. Blake inquired in what state the horny scutes of the Chelonia are preserved.

The Author said by impressions on the underlying bone. In the Stonesfield Slate the scutes themselves of the *Testudo Stricklandi* of Phillips are preserved.

33. Notes *on the* Hornblende-schists *and* Banded Crystalline Rocks *of the* Lizard. By Major-General C. A. McMahon, F.G.S. (Read May 22, 1889.)

I have visited the Lizard on three occasions, namely, in 1887 in company with several Members of the Geologists' Association under the able guidance of Messrs. Howard Fox, F.G.S., and E. A. Wünsch, F.G.S.; in 1888 by myself; and in February of the present year in company with Mr. Howard Fox, to whom I feel under the greatest obligation, his intimate acquaintance with the Lizard rocks and his local knowledge rendering his aid in the field extremely valuable.

On each occasion I collected numerous specimens of the rocks, and studied thin slices of them under the microscope during the intervals between my visits, so that I have had an opportunity of correcting the impressions made in the field by microscopic work in the study, and of again testing ideas formed in the study by fresh observations in the field. I have examined under the microscope over ninety thin slices of my own specimens, nearly fifty have been lent me by Mr. Howard Fox, and Mr. J. J. Harris Teall kindly placed those of his own collection at my disposal.

Before stating the results of my own investigations I think it desirable to refer briefly to the views expressed by previous observers. Sir Henry De la Beche's opinion may be gathered from the following extract from his 'Report on the Geology of Cornwall and Devon'*:—"If it were not for the occurrence of the hornblende slate in the conglomerate of the Nare Point, we might suppose that it [the hornblende slate] was a mass of that trappean or ancient volcanic ash which is detected so abundantly amid the grauwacke of Devon and Cornwall, upon which the mass of serpentine and diallage rock, now nearly covering it up, has been poured in a melted state; and that being thus retained long beneath it in a heated condition, the water amid its loose laminæ prevented from escape upwards by the hot rock above, the hornblendic and felspathic particles of which it was composed arranged themselves into crystalline forms, the mass retaining its original laminated structure. . . . It must, however, be confessed that, unless we suppose the hornblende slate, in the conglomerate of the Nare Point, to be derived from some other source, this explanation is not so good as could be desired."

The blocks in the conglomerate alluded to are said by De la Beche, in another place (Report, p. 94), to be "generally decomposed," and his correlation needs confirmation, especially by the modern methods of microscopic investigation; but even if the rocks which supplied the boulders were satisfactorily shown to be the hornblende-

* Report, p. 34.

schists of the Lizard, it would prove no more than that the hornblende-schists are of great geological antiquity (they have been referred to the Archæan age by Professor Bonney *), and this fact would not stand in the way of our assigning a volcanic origin to them.

Professor Bonney, in his second paper, "On the Hornblendic and other Schists of the Lizard District" †, was the first to point out "that in addition to the 'talco-micaceous' schists of De la Beche and the normal hornblende-schists there is a third group" (the 'granulitic') which was, he supposed, "deposited by rather variable currents in waters of no very great depth" ‡.

In his annual Address as President of the Geological Society, in 1886, Prof. Bonney gave a summary of his conclusions regarding the metamorphic schists of the Lizard, part of which it is desirable to to quote:—"In the lowest series [viz. the micaceous] bedding is indicated by distinct mineral changes visible to the eye in the field, and fully confirmed by microscopic examination. In the upper series [viz. in the 'granulitic' group] there is just the same rapid alternation of bands widely differing in mineral character that I have described in the melanite-schist series of Val Piora. Hence, if we were to give up the false-bedding which I have described in the middle group [viz. the hornblende-schist group] (though, after careful reconsideration, I feel it very difficult to explain this as the result of mechanical movements), and were to assume the whole group to be a mass of crushed dolerites affected by mineral changes (which a part may very well be), still there is, above and below this, evidence of stratification. Further, even if we reduce the apparent bedding throughout to gliding planes, and suppose the whole series to be some extraordinary complication of mashed-up igneous and sedimentary rocks (which I regard as most improbable), there can, even then, be no question that this rolling out, this metamorphism of the most exaggerated kind, is anterior to the intrusion of the peridotite (now serpentine), the gabbro, and the granite, from which all signs of crushing (save some local disturbance near a fault) are absent" §.

Mr. J. J. Harris Teall, F.G.S., on the other hand, in 1887, expressed the following opinion:—"I submit, therefore, that the rocks of the Lizard District referred to in this communication ||, and which constitute the greater portion of Prof. Bonney's granulitic series, are of igneous origin, and that the parallel structure which characterizes many of them has nothing to do with stratification in the ordinary sense of the word, but is a consequence of the deformation to which the original rock-masses have been subjected. It is undoubtedly true, as Prof. Bonney has pointed out, that many of the rocks are largely composed of broken crystals, and may be said therefore to possess a clastic structure, if we use the term clastic in its etymolo-

* Quart. Journ. Geol. Soc., Ann. Address, 1886, vol. xlii. Proc. p. 86.
† *Ibid.* vol. xxxix. p. 1.
‡ *Loc. cit.* pp. 2, 5.
§ *Ibid.* vol. xlii. Proc. p. 86.
|| "On the origin of certain Banded Gneisses," Geol. Mag. 1887, p. 491.

gical sense. But there is no proof that the fragments have been deposited as such. The original minerals may have been broken during the deformation of the rock-masses. This, I believe, is what has actually taken place. The structures are of the kind for which Prof. Kjerulf has proposed the term cataclastic."

Still more recently Mr. Alexander Somervail, in communications to the 'Geological Magazine' *, asserts the "igneous origin" of the whole of Prof. Bonney's granulitic group, and he points to the dyke in serpentine at the extreme north end of Pentreath Beach as a portion of this "granulitic group," and states that, "at the west end of Kennack Cove, the dykes cutting the serpentine are seen to coalesce with the granulitic rocks forming the foreshore." Mr. Somervail concludes that the granite, diorite, and other varieties of rock specified in his paper "have been differentiated out of the same magma during the cooling process, the ordinary selective law of chemical affinity separating the basic from the acidic types." He adds in a subsequent communication † that he does not know any separation between the beds of the "granulitic" group and the hornblende-schists save in the extremes of their compositions."

The above extracts show that the geology of the Lizard District is still in a very unsettled state in respect to some material points.

Hornblende-schists.

I pass on now to offer some remarks on the hornblende-schists.

These rocks, in the area covered by this paper, namely the coast-line from the Lion Rock, Kynance Cove, on the west coast, to Kennack Cove on the east coast, are bedded crystalline schists in which the foliation is strictly parallel to the bedding. The dip is, on the whole, very flat, and being nearly flat it wavers about considerably, ranging from W.N.E. (magnetic) round by E.N.E. and E. to S.S.E.

The following table (p. 522) gives a summary of the result of the microscopic examination of 16 samples of schists from the hornblende-schist area.

The first point to be noted, and the result was a surprise to me, is that none of the samples entered in the above list contain quartz. In this respect they present a striking contrast to the rocks of the granulitic group (a microscopic analysis of which is given further on, p. 532) and the rocks of the metamorphic series below the hornblende-schists.

The next point to be observed is that all the samples, without exception, contain felspar. This mineral forms the base in which the other minerals are set; much of it exhibits the twinning of the triclinic system, but, as a rule, it is much kaolinized or in other ways altered. Here and there it is water-clear, but the presence of polysynthetic twinning, or the character of the interference figure in converging polarized light, shows conclusively that the clear mineral is felspar and not quartz.

* Geol. Mag. 1888, pp. 46, 553.
† *Ibid.* 1889, p. 96.

Table of Hornblende-schists.

	Localities from which the specimens were taken.	Hornblende.	Felspar.	Augite.	Sphene.	Apatite.	Magnetite*.	Pyrites.	Epidote.	Calcite.	Chlorite.	Mica.	Analcime.
1.	Between Caerthillian and Lizard Head	H	F	...	...	...	Ma	Py					
2.	Bumble	H	F	...	Sph								
3.	Penolver Point	H	F	Aug	Sph	...	...	...	...	Ca	...	...	An
4.	Quarry between Landewednack Church and Church cove	H	F	Aug	Sph	...	...	...	Ep				
5.	Ditto	H	F	Aug	Sph	Ap							
6.	Ditto	H	F	Aug	Sph								
7.	Church Cove	H	F	Aug	Sph	Ap	Ma	...	Ep				
8.	Cove between Church Cove and Pen Voose	H	F	...	Sph	Ap	Ma	...	...	Ca	Chl		
9.	Ditto	H	F	...	Sph	Ap	Ma	...	...	Ca	Chl		
10.	Ditto	H	F	...	Sph	Ap	Ma	...	...	Ca	Chl		
11.	Chough Ogo	H	F	...	Sph	...	...	Py					
12.	Carn Barrow	H	F	...	...	...	Ma	Py					
13.	Ditto	H	F	...	...	...	Ma	...	...	...	...	Mi	
14.	Ditto	H	F	...	Sph	Ap	Ma	Py					
15.	Ditto	H	F	...	Sph	Ap	Ma	Py					
16.	Cadgwith	H	F	...	...	...	Ma						
		16	16	5	12	7	10	5	2	4	3	1	1

Sphene, it will be seen, is present in nearly all the specimens; apatite may be detected in 7 out of the 16 samples, whilst iron, in the form of magnetite, pyrites, or ferrite, is common.

Carbonate of lime occurs in four slides; epidote in two; mica and analcime in one each.

The most unexpected mineral found in these schists is malacolite or a colourless augite; it occurs in five of the specimens entered in the foregoing list, and as its presence in the hornblende-schists of the Lizard has not hitherto been noted, it may be as well to give some details regarding it. No. 3 of this list was taken from the top and extreme edge of an inaccessible cliff at Penolver Point. This is a somewhat remarkable rock; macroscopically examined it does not materially differ in appearance from an ordinary hornblende-rock in which the foliation is obscure; but under the microscope it is seen to be a finely granular mixture of felspar, augite, hornblende, and sphene. It is perfectly holocrystalline in structure. The augite is in rounded granules and it is almost as abundant as the felspar. The hornblende is a secondary product and it is more abundant along one zone than in the rest of the slice. Indeed this tendency of the hornblende to arrange itself in zones constitutes what there is of foliation in the rock. The augite and felspar exhibit no parallelism in the mutual arrangement or in the orientation of their crystals. The slice supplies abundant

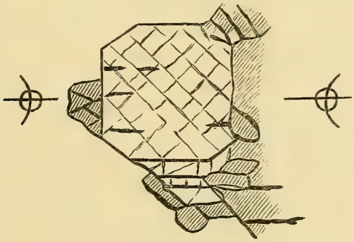
* This includes ilmenite and ferrite.

evidence that the hornblende is a secondary product after augite ; for the conversion of the one into the other may be distinctly traced, and the predominance of the hornblende in some zones, more than in others, indicates that the augite was converted into that mineral more freely along certain planes than in the spaces between them.

The three specimens that follow in the list were taken from a quarry on the roadside, between the Landewednack Church and Church Cove, which is worked for road-metal. The rocks here are quite typical hornblende-schists. The fourth specimen was taken from the landing-place in Church Cove, and belongs to a slightly lower horizon than the rocks in the quarry. Under the microscope these four specimens are seen to be distinctly foliated rocks, felspathic bands alternating with bands in which the felspar is subordinate to hornblende. The remarkable feature in these slices is that they contain an abundance of augite, the latter mineral being restricted to the felspathic bands.

The pyroxene in the above specimens, which appears to belong to the species malacolite, is colourless in thin sections, but it has a faint greenish tint in thick slices. It possesses no dichroism ; it is occasionally traversed by little canals of aqueous origin similar to those so commonly seen in olivine and enstatite ; it is occasionally idiomorphic, and still more frequently exhibits the characteristic cleavage-lines of augite. The sections that show well-marked cleavage-lines intersecting each other at an angle within two or three degrees of 90° exhibit interference-figures in converging polarized light, and the major axis of elasticity bisects the obtuse angle of the rhomb formed by the lines of prismatic cleavage. These facts show that the mineral is augite and not epidote. The following sketch of a crystal taken from one of my slices will, I doubt not, be recognized by petrological microscopists as that of an almost typical augite.

Fig. 1.—*Section of an Augite Crystal partially surrounded by Hornblende.*



In case, however, any doubt should linger in the minds of those who have not had an opportunity of critically examining these slices regarding the presence of malacolite in them, I may mention that I showed all my specimens to my friend Mr. J. J. Harris Teall, F.G.S., and he had no doubt as to the identification of this mineral. Moreover, he was kind enough to re-examine some of his own specimens

of hornblende-schists from Polurrian, Cadgwith, and Hot Point, situated on the east and west coasts of the Lizard, and found that they also contained good specimens of malacolite. It is clear, then, that the presence of pyroxene in the hornblende-schists of the Lizard is not a mere local peculiarity limited to one place.

The extracts from the writings of previous observers given in the preceding pages show that the idea of attributing an original volcanic origin to the hornblende-schists of this district naturally suggested itself to those first in the field; and I think the study of these rocks under the microscope goes a long way to confirm this diagnosis. Not only are all the minerals found in them, minerals commonly found in rocks of volcanic origin, but the microscope strongly supports the inference that the hornblende, which now enters so largely into their composition, is a secondary product after augite, and that the beds, when originally deposited, were composed principally of felspar and pyroxene. Malacolite may be seen in the thin slices described above in every stage of conversion into hornblende. Not only are malacolite-crystals surrounded by hornblende, but in many cases a single crystal may be seen to consist in part of augite and in part of hornblende.

De la Beche, we have seen, was disposed to regard the hornblende-schists as "a mass" of altered "ancient volcanic ash" which is "to be detected so abundantly amid the grauwacke of Devon and Cornwall;" and I think it highly probable that not only the hornblende-schists but also a portion of the "granulitic group" were originally made up of volcanic ash intermingled with beds of lava. The origin of ancient rocks so highly altered as the Lizard schists are, must be more or less a matter of inference. Direct proof is out of the question; but the available evidence points, I think, in one direction and in one direction only. The absence of free quartz is very much against the supposition that they were originally sedimentary rocks of an ordinary character; their mineralogical contents strongly suggest an igneous origin of some sort; whilst the fact that they are bedded indicates that they belong to the volcanic, and not to the plutonic class.

But, admitting their volcanic origin, to what agency are we to attribute the present foliated and banded appearance of the hornblende-schists? I have searched in vain for evidence to show that the banding is due to dynamic deformation after the consolidation of the rocks. The hornblende-schists and the "granulitic" group, it is true, are cut up by numerous small faults; they are cracked, and portions of them have been forced to slide over other portions; but these slidings have been for short distances and the throw of the faults seems, as a rule, to have been small*. I have examined under the microscope the junction of sliding planes in two cases; but no mica was found at the line of contact, and the latter gives no evidence of any chemical or mineralogical action having been set up by friction. I have not come across a single faulted felspar in the hornblende-schists, and I have not found evidence to prove that

* Bonney, Quart. Journ. Geol. Soc. xxxix. p. 5, footnote.

they were subjected to severe crushing *. Moreover, it is evident that the very existence of cracks and fractures shows that the rocks which now display these marks of strain must have been rigid when the fractures took place, and their continued presence demonstrates that the dynamic heat developed was insufficient to induce recrystallization.

Whatever may be said of other rocks, I find it impossible to account for the fine banding of the hornblende-schists on the supposition that these bands were produced by a series of sliding planes. Not only would the regular succession and alternation of these thin bands present a serious objection to the acceptance of this explanation, but it is obvious that the shearing of a solid rock into such extremely thin layers would have developed heat sufficient to fuse the whole mass, in which case it would have lost its banded structure and have assumed that of a hornblende-granite. The stripes are so sharply defined and thin that several of them can be seen in a slice mounted on an ordinary microscopic slide. The supposition that these bands were originally thick and were drawn out into streaks of thread-like thinness by stretching is not supported by the microscopic evidence, and it fails to explain how the hornblende segregated into a series of parallel zones. The felspars that make up the base of the rock do not exhibit in their orientation or shapes the marks of stretching and deformation which are strikingly displayed in some of the foliated gabbros of the Lizard. The rock is not composed of thin shavings of two or more different rocks; the microscope shows that there is no difference in substance, or structure, between the base of the white and the base of the black bands; the rock seems to have originally been a homogeneous one, and the banding to have been produced at a later stage in its history by the segregation of the hornblendic element in planes parallel to the bedding. The main question seems to me to be, How has this segregation of hornblende been produced?

One of the most important agents in bringing about the banding of the Lizard hornblende-schists appears to me to have been water. The rocks themselves, when interrogated with the aid of the microscope, give abundant evidence of the presence and action of water, and the competence of this agent, aided by heat and pressure, to bring about great mineralogical and structural changes can hardly be doubted. Indeed, the Lizard rocks have been penetrated by and have yielded to the action of aqueous influences so completely that they may almost be said to have been stewed in water. The Lizard serpentine which covers so large an area, and which still bears on its bosom so many traces of the potent agent that reduced this ancient peridotite to its present condition, may be appealed to with confidence to prove the truth of this assertion.

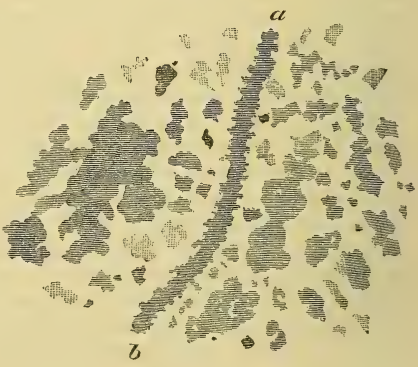
Water—and I omit for brevity sake all allusion to the carbon dioxide and other chemical reagents with which it is usually charged—appears to penetrate rocks through such fine pores that, more often than otherwise, its former presence can only be inferred from

* See also Bonney, *ante*.

the effects it has produced. Such minerals as olivine, enstatite, and, less commonly, augite are, indeed, frequently scored with the canals formed by the aqueous agents of decomposition in their passage through them ; but we can seldom trace the channels through which they gained access to these minerals. The Lizard rocks, however, seem to have been so completely penetrated by heated water that it has worn numerous canals in the body of the rocks themselves by which its former presence may be directly traced. Channels now stopped with fibrous or amorphous serpentine, with calcite, chlorite, steatite, and other products of aqueous action, may be seen wending their sinuous course in all directions, here widening into a lake-like expanse, there contracting into a narrow canal. In other places the channels through which the liquid that effected the decomposition of the felspars sapped its way may be distinctly traced by the fringing lines of magnetite, ferrite, or limonite, left, like sea-weed on the shore, to mark the margin of the once flowing streams. On either side of these streams we may also observe how the liquid overflowed its banks—to continue the metaphor—and flooded the felspars on either side, converting them into the isotropic substance that now stops the canals themselves. The following illustrations (figs. 2, 3) represent one of these canals. The left-hand sketch shows the canal as seen in ordinary transmitted light, the right-hand one gives the same canal with a portion of the surrounding felspar in polarized light.

Fig. 2.—*Canal in Hornblende-schist.*

Fig. 3.—*Canal under Polarized Light.*



The illustration given in fig. 4 is a sketch of a portion of one of the meandering streams alluded to above. The lower portion of a large lake-like expanse filled with serpentinous matter is shown at *e*. Below this the main stream follows a winding course until it strikes the crack *c-d*, which dies out at *d*, follows it for a little distance and then striking off from it, makes its way into another lake, the

beginning of which is seen at *f*. At *g* a second more imperfectly marked stream is seen flowing from *e* to *f*. The presence of

Fig. 4.—*Serpentinous Streams.*

chlorite, calcite, limonite, analcime, and epidote (which usually contains over 2 per cent. of water * in its composition) affords presumptive evidence of the action of water; for these minerals are commonly found in the amygdules of lavas; and it is worth mentioning that some cracks in the rocks under description in this paper contain hornblende, plagioclase, and sphene, from which I infer that they also may sometimes be formed in what Bischof terms the "wet way," a fact that has already been demonstrated by that author in respect of felspar, and less clearly shown in the case of hornblende †.

I shall have to allude to the case of hornblende and felspar further on, but I may mention here that the agency of water in the conversion of augite into hornblende may be distinctly traced in the slices that still contain pyroxene, for the canals left by the percolation of the water may be clearly observed in the hornblende when examined with a $\frac{1}{5}$-inch objective. Countless instances of this may be seen.

These slices also afford evidence that, in some cases at all events, the mica found in them has been formed in the wet way. One specimen in particular, a fragment from the "granulitic" group at Kennack Cove, deserves especial attention. Macroscopically considered, this looks very much like a fragmental rock and seems to consist of

* J. D. Dana's 'System of Mineralogy,' 5th ed. p. 283, and E. S. Dana's 'Text-Book,' 2nd ed. p. 285.

† 'Elements of Chemical and Physical Geology,' by Gustav Bischof.

felspars set in an interstitial paste. Under the microscope it is seen to consist of decomposed felspar through which water has percolated in all directions. These streams are always winding and tortuous except when, here and there, they have temporarily followed the course of a crack. These streams, which alternately widen out into broad lacunæ and contract into narrow channels, are marked by fringing borders of opacite, limonite, and magnetite, and they are stopped in part by an isotropic serpentinous mineral, and in part by a rich red, strongly dichroic mica, which, in every case, is orientated in the direction of the serpentinous stream that contains it, the basal cleavage of the mica being strictly parallel to the sides of the stream. Whatever view may be adopted regarding the origin of this rock, there can, I think, be no doubt that the mica, like the serpentinous matter that surrounds it, is a secondary product of aqueous action.

The access of water to solid rocks and the heating of this water in rocks deeply buried under superincumbent strata are ideas which are so familiar to geologists that I need not spend any time on this branch of the inquiry, but pass on to point out how heated water may have produced the banding of the Lizard hornblende-schists.

I need also, I should think, devote little space to showing the high probability that fine-grained ash-beds of subaqueous origin*, after consolidation by the pressure of superposed deposits, would favour the passage of underground water along the planes of lamination more readily than in a direction perpendicular to those planes.

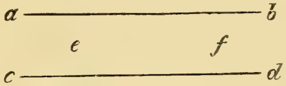
When inspecting jails in India, the process of paper-making by hand interested me much and furnished an illustration capable of a geological application. The material of which the paper is made floats in a vat of water. A sieve is plunged into this vat, and the pulpy matter suspended in the water is allowed to settle on it for a few seconds. As soon as the requisite thickness is attained the sieve is withdrawn, and the newly formed film is there and then deposited on a heap of similar films until a large block is formed. One would naturally expect the whole series of wet films to consolidate into an amorphous lump, but, contrary to one's expectations, sheet after sheet is removed without difficulty, and after having been dried in the sun, is polished and used as writing-paper. This process has often struck me as a pretty illustration of how pauses, of even short duration, in the deposition of sedimentary rocks may help to produce a fissile structure. This tendency, moreover, would be greatly increased by the compression caused by the weight of superposed strata. The slates of the Himalayas are nearly all lamination-slates, but they are as truly fissile in the direction of the lamination as English slates are in the direction of cleavage.

Let us suppose that fine-grained ash-beds divided by planes of sedimentation, or of cleavage parallel to the bedding, were subjected to the action of heated water in which a periodical movement, however languid, had been set up (see fig. 5). During the pauses in the flow, the heated water in the plane (a–b) would percolate by gravitation and

* See Bonney, *ante*.

capillary attraction into the space (e–f). Similarly the water that had been flowing along (c–d) would find its way into the space below it. As a result of this slow percolation chemical action would be set up in the body of the rock between the planes of lamination. Now suppose the flow along the planes (a–b) and (c–d)

Fig. 5.



were to be reestablished, the liquid in the rock above (a–b) would be drained off by (a–b) and the water in the space (e–f) would be drained by (c–d): for the flow along (a–b) and (c–d) being more easy than in a transverse direction, the supply from (a–b) into (e–f), and from (c–d) into the space below, would decline, and the force of gravity would carry the water in (e–f) downwards into (c–d).

That such periodical currents would be established in water-bearing strata adjoining the roots of active volcanoes I think highly probable. Considering the amount of water in the form of steam given off by active volcanoes, and considering the tremendously explosive character of the periodic discharges from some craters, powerful suction must, I think, follow each explosive discharge, which must affect the water-bearing strata in which the roots of volcanoes are planted. This powerful suction * and pumping action is sufficient, it seems to me, to account for a periodic capillary flow of water in strata within the range of a volcano's influence comparable, as regards the character of the flow, with the circulation of fluids in the tissues of animal and vegetable bodies.

That our ancient volcanoes did, as a matter of fact, exhibit explosive action of the most powerful kind and on the most extensive scale, no one can doubt who has examined the extensive deposits of the Charnwood Forest, which range from the finest ash to coarse agglomerates in which the blocks are several feet in diameter. Prof. Bonney and others tell us that the Charnwood-Forest deposits belong to the Archæan series; and at all events no one will deny that they belong to a pre-Carboniferous age.

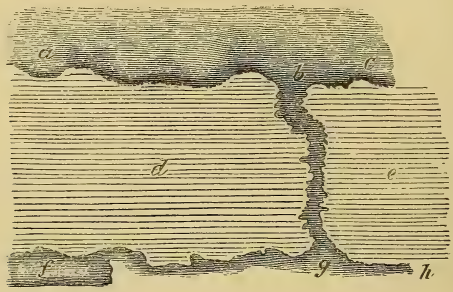
In these Charnwood-Forest rocks ash predominates and lava-beds are very subordinate. Ash-beds, moreover, according to the Geological Survey Report already quoted, are to be found in abundance in Cornwall itself, and the beds that contain them are as old, according to present received opinion, as the Ordovician age.

That water has flowed, or percolated, through the Lizard hornblende-schists in the direction of the banding is not altogether a matter of inference or theory. In the following illustration (fig. 6) I give a sketch taken from one of those banded hornblende-schists.

* The vigour of the response to this suction would, of course, depend on the porosity of the rock and the "head" of the water permeating it.

The passage of water from the upper felspathic band (*a–b–c*) to the lower felspathic band (*f–g–h*) by the channel (*b–g*) through the dark hornblendic band (*d–e*) is clearly demonstrated. The fact that the liquid that effected the decomposition of the felspar also flowed

Fig. 6.—*Passage of Water through Banded Hornblende-schists.*



along the bands (*a–b–c*) (*f–g–h*) is shown by the hard marginal line left by this liquid along the border of the hornblendic band (*d–e*) by the formation of a secondary product of decomposition, opaque in transmitted, and dead white in reflected light.

I suppose, then, to conclude my remarks on this branch of the subject, that the banding of the hornblende-schists was produced by the capillary flow, or percolation, of heated water through the rocks in two ways, namely, by the leeching out of unstable minerals (such as pyroxene) from the spaces between the planes of lamination, and by the formation of comparatively stable minerals (such as hornblende) along these planes.

Numerous illustrations of the growth of hornblende in the "wet way" are contained in the thin slices under description. In three of my specimens of diorite cracks were formed which in some cases divided crystals of hornblende in half, and in others separated adjoining crystals, the severed hornblendes being left on opposite sides but at the extreme margin of the cracks. In both these cases the cracks have been bridged over, not by the mineral that stops them in other places, but by hornblende. Sometimes this is in the form of actinolite needles, and in others in that of substantial crystals. In some cases the crystals, split in half by a crack, have been repaired in the most perfect manner by the insertion of hornblende in optical and isomorphic continuity with the severed ends. The secondary portion of the composite crystal, however, does not exhibit the dark colour and strong dichroism of the severed portions of the original crystal at the two ends of the new crystal. The stopping of these cracks is clearly not due to the exudation of uncrystallized magma from the body of the rock before its complete solidification. The extreme sharpness of outline presented by these cracks shows that the crystals in the rock were rigid when the

rupture took place, and the fact that the new hornblende which joins the severed portions of divided crystals differs radically in colour from the old hornblende is unfavourable to the supposition that it was supplied directly from the uncrystallized magma prior to the consolidation of the rock. The correctness of this inference is further shown by the fact that the felspar that stops the major portions of the cracks in these specimens is water-clear and presents a striking contrast in this respect to the clouded, semi-opaque, and highly decomposed character of the felspar in the body of the thin slices. Undoubtedly these cracks were stopped by a secondary process after the consolidation of the rock; and that this was not a dynamic process connected with shearing or friction is shown by the fact that the cracks do not exhibit faulting even on a microscopic scale. The lesson to be derived from the above examples seems to me to be an important one. If we hold a sheet of paper at a slope with a magnet under it and allow fine fragments of pounded minerals to slide over the surface of the paper, minute fragments of magnetite will, if the pounded rock contains magnetite, be arrested by the magnet whilst the fragments of other minerals will slide past. A similar polar influence appears to have been exercised by the molecules of the hornblende-crystals at the edges of the cracks on the material in aqueous solution that dribbled past them, and the chasm that divided the ruptured fragments of hornblende was thus bridged over.

May we not apply the lesson taught us by these cracks to explain the banding of the hornblende-schists of the Lizard, and suppose that a like polar influence was exercised by hornblende-crystals already formed along the lines of sedimentation, or of lamellar cleavage, on the molecules carried past them by the water percolating through the rock, and that as the water charged with hornblendic material flowed slowly along the planes of deposition, in the way suggested, a segregation of hornblende along these lines took place and the banding was thus produced?

The explanation above suggested is only intended to apply to the banding; for ordinary unbanded hornblende-rocks and hornblende-schists it is not necessary to suppose that water flowed through the rock in planes parallel to the bedding. Heated water was, I see good reason to believe, the principal agent in bringing about the conversion of the pyroxene in these old products of volcanic action into hornblende; but if, subsequent to this conversion, the heat derived from either plutonic or dynamic causes was sufficient to reduce these rocks to a plastic, or semi-plastic, condition without actually fusing them, the materials would arrange themselves under the pressure of superincumbent strata in a direction parallel to the strata.

The "Granulitic" Group.

I now pass on to consider the "granulitic" group, and it will be convenient, I think, to preface my remarks by giving a summary in

a tabular form of the result of the microscopic examination of some samples of them collected by me.

No.	Locality from which the specimens were taken.	Hornblende.	Felspar.	Quartz.	Mica.	Apatite.	Sphene.	Magnetite.	Chlorite.	
1	Pentreath Beach	H	F	Q	Mi	Ap	Sph	Ma	...	f
2	ditto	H	F	Q	Mi	Ap	Sph	Ma	...	f
3	Pen Voose	H	F	Q	Mi	Ap	Sph	Ma	Chl	b
4	ditto	H	F	Q	Mi	Ap	Sph	...	...	f
5	Cadgwith	H	F	Q	Mi	Ap	Sph	Ma	...	f
6	ditto	H	F	Q	Mi	Ap	Sph	Ma	...	f
7	Pen Voose	H	F	Q	Mi	Ap	Sph	...	...	f
8	Pentreath	H	F	...	Mi	Ap	...	Ma		
9	Flag-staff Quarry, Cadgwith .	H	F	...	Mi	Ap	Sph	...	..	f
10	Pen Voose	H	F	...	Mi	...	...	Ma	...	b
11	Kennack Cove	H	F	...	...	...	Sph			
12	Pen Voose	H	F	Q	Mi					
13	ditto	...	F	Q	Mi	Ap	...	...	Chl	w
14	ditto	...	F	Q	Mi	Ap	Sph	Ma	...	w
15	Flag-staff Quarry, Cadgwith .	...	F	Q	Mi	Ap	Sph	...	Chl	f w
16	ditto	...	F	Q	Mi	Ap	Sph	Ma	Chl	
17	Pentreath	...	F	...	Mi	...	...	...	...	f
18	Kennack Cove	...	F	...	Mi	...	...	Ma		
19	ditto	...	F	...	Mi	Ap				
	Granites undoubtedly intrusive in the "Granulitic" group.									
20	Pen Voose	...	F	Q	Mi	Ap	...	...	...	f
21	ditto	...	F	Q	Mi	Ap	...	...	...	f
22	Cadgwith	...	F	Q	Mi	Ap	...	...	...	f
23	ditto	...	F	Q	Mi	Ap	...	...	...	f
		12	23	16	22	18	12	10	4	

f. Indicates that these specimens are more or less foliated.
b. Specimens taken from black bands in the granulitic rocks.
w. Specimens taken from white bands in the granulitic rocks.

Felspar, it will be observed, is common to all the specimens. It forms the base in which the other minerals are imbedded, and here and there it exhibits the twinning of plagioclase. It is generally more or less decomposed, but it is occasionally water-clear.

The felspar in all these rocks affords more or less evidence of incipient saussurization; round patches, opaque in transmitted light, and of pearly white colour in reflected light, have been formed here and there, which have no definite relation to the shape of the crystals containing them. Possibly the granular appearance often given to the rock by these white spots may have suggested the term "granulite." If so it simply denotes the progress of decay and gives no clue to the original structure of the rock.

Mica is another mineral found in all but one of the samples. The predominant type is a mica at one end of the scale and a chlorite at the other; but it is often difficult to say regarding the interme-

diate variety whether it is a mica or a chlorite. This intermediate variety is highly schillerized along the cleavage-planes, but the spaces between these planes are not green but of an extremely pale buff-colour. This variety either does not polarize at all or, more frequently, exhibits a peculiar bluish neutral tint between crossed nicols. The Lizard granites contain a mineral closely resembling the species above described, and I regard it in both cases as a degraded biotite. Some slices of the "granulite" (as also of the granites and porphyritic diorites) contain, in addition to this, a rich red-brown mica that polarizes brilliantly.

Apatite is present in all the slices save five, and it is often rather abundant. Sphene is found in 12 and quartz in 16 out of the 23 slices entered in the list. The quartz abounds in liquid-cavities with moving bubbles; and sphene, when present, is usually abundant. Hornblende is sparse in one and is wholly absent from 11 slides.

The microscopic examination (summarized in the preceding table) shows that the "granulitic" group consists of an intermixture of granite and diorite, and it is favourable to the view, detailed below, that the white bands in this group are veins of granite injected into dioritic rocks from neighbouring eruptive masses. The presence of hornblende in some of the granitic portions and of mica in the diorite is probably due to contact action.

Compared with the hornblende-schists the "granulites" differ in their mineralogical contents by the absence of hornblende in 11 out of 23 samples; in the presence of quartz in all but 7 of the specimens; and in the occurrence of mica in all save one, whereas only one of the hornblende-schists contains this mineral. Apatite, sphene, and iron-oxides are common to both series. The quartz in the "granulites" is of an essentially granitic type.

Prof. Bonney regarded the "granulitic" group as mainly composed of bedded rocks; but Mr. Teall held that true igneous rocks form no inconsiderable portion of this group. Both views are, I think, correct. Part of the basic portion of the "granulitic" group is, it seems to me, composed, like the hornblende-schists, of volcanic ashes and lavas, which thermo-aqueous agencies, succeeded by the contact-action of igneous masses, have reduced to a condition which renders it impossible, in some cases, to distinguish between them and the diorites that have invaded the rocks of this group.

One of the intrusive diorites is well seen at Polbarrow, where a broad dyke of it cuts right across the "granulitic" group between the ruined boat-house and the cliff. Down below veins of it may be seen intruding into the "granulite." This is No. 1 of the microscopic summary given further on. It is an excessively tough, hard rock.

Another very interesting and important intruder is the porphyritic diorite, to which attention was called by Mr. Teall in a paper read before the Geologists' Association in April 1887 *, and by Messrs. Howard Fox, F.G.S., and Alex. Somervail, in a paper read at the meeting of the British Association in September of that year †.

* 'Proceedings,' vol. x. p. 75. † Geol. Magazine, February, 1888, p. 74.

The eruptive character of this rock is undoubted. At low water, during spring-tides, the reefs outside the island at Polpeor are exposed for about a mile from the shore. The porphyritic diorite may be seen in these reefs cutting right across the strike of the gneiss. Nearer land it is an intruder in the green schists, generally following their bedding, but constantly shifting from one horizon to another; whilst in the cliffs of the mainland it frequently shows itself at a still higher horizon among the micaceous and hornblendic schists.

This rock is a very frequent intruder in the "granulitic" group, and as it appeared prior to the last intrusion of granite, and has the habit, in this group, of following the lines of bedding, its true character might easily be overlooked by an observer who had not made himself familiar with it in localities (like the reef outside Polpeor) where its igneous nature is evident.

This diorite is often profusely porphyritic, but sometimes the porphyritic crystals of felspar are small or sparse, and occasionally they are absent, when it becomes impossible to distinguish it from an ordinary diorite. Now and then (as in one or two places in the Polpeor cliffs) it becomes foliated.

The following table gives a summary of the microscopic examination of several samples of the "porphyritic" and other diorites.

Intrusive Diorites.

	Locality from which the specimens were taken.	Hornblende.	Felspar.	Quartz.	Mica.	Apatite.	Sphene.	Magnetite.	Chlorite.	Analcime.	Remarks.
	Diorites.										
1.	Polbarrow	H	F	Q	Mi	Ap	Sph	Ma			
2.	Between Chough Ogo and Polbarrow *	H	F	...	...	...	...	...	...	...	In serpentine, in apparent line of strike with No. 1.
3.	Between Polbarrow and Cadgwith	H	F	...	...	Ap	Sph	...	Chl		
4.	Between Caerleon and Kennack Coves	H	F	...	...	...	...	...	...	...	In serpentine.
	Typical Porphyritic Diorites.										
5.	South of Kynance Cove	H	F	...	...	Ap	Sph	...		An	
6.	Polpeor Cove	H	F	...	...	Ap	...	Ma			
7.	ditto	H	F	...	...	...	...	Ma			
8.	Caerleon Cove..................	H	F	...	Mi	...	Sph	Ma			
9.	ditto	H	F	...	Mi	...	Sph	Ma			
10.	ditto	H	F	...	Mi	...	Sph	Ma	Chl		
	Diorites of Doubtful Class.										
11.	Kennack Cove	H	F	...	...	...	Sph				
12.	ditto	H	F	...	...	...	Sph				
13.	ditto	H	F	...	...	Ap	Sph	...	Chl		
14.	ditto *	H	F	..	Mi	Ap	Sph				
		14	14	1	5	6	10	6	3	1	

* Parallelism of structure is developed in No. 2 and No. 14.

Much of the felspar is visibly triclinic, and the rest, in which polysynthetic twinning is not apparent, presumably belongs to this system.

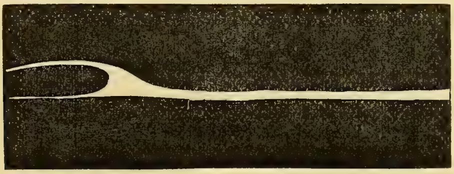
As compared with the specimens entered in the table of "granulitic" rocks (*ante*, p. 532) the chief difference to be observed is the absence of quartz (the Polbarrow trap is the only exception to this rule) and the comparative infrequency with which mica is met with in the true eruptive diorites.

Saving in the absence of augite in the above diorites, and the almost total absence of mica in the hornblende-schists, there is little or no difference in mineralogical composition between the hornblende-schists and the true intrusive diorites described in this paper. As before stated, there is absolutely no distinction to be made out under the microscope in the structure of the ground-mass of some of the porphyritic diorites and some of the hornblende-schists—a result which would be startling were we not to hold that the latter consist of the recrystallized products of volcanic action.

The difficulty in distinguishing between converted ash-beds and intrusive diorite, when the latter inserts itself between the planes of lamination, is increased by the fact that granite has been injected into the intrusive diorites as well as into the sedimentary beds of the "granulitic" group. This is well seen at Kennack Cove, where bands of porphyritic diorite occur abundantly in what is, petrologically considered, an ordinary diorite. Both have been injected with granite in the way characteristic of the "granulitic" group.

The rocks of this group are usually spoken of as a banded group, and appearances often support the idea that the quasi-banding is a regular banding parallel to the bedding. When the eye of the observer becomes accustomed to these rocks, however, the banding is seen to be extremely irregular in character. Not only do some of the bands dwindle into strings and die out in the direction of their length, but they inosculate, bifurcate, and entangle themselves into a complicated network of meshes, and they swell in places into broad lacunæ, which, in their turn, throw off fine veins in all directions. Even where these bands are apparently most regular they will often be found, when followed up, to behave like injections. An example is given in fig. 7 below.

Fig. 7.—*Forked Band in the Granulitic Group.*



The above description shows the unstable character of the quasi-bands when examined in the direction of their length. In the direction of their breadth their extension is equally unlike that

of regular banding. For instance, I observed near the Lion Rock a jutting cliff of the "granulitic" group injected in the usual way with numerous granite-veins on one of its sides, none of the quasi-bands, however, intruding so far as the opposite side of the rock. The same thing may even be seen in one of my hand-specimens. In the latter only the strongest of the veins have penetrated right through the substance of the specimen from side to side. This condition of things is exactly what might be anticipated on the hypothesis of injection; for at a certain distance from the focus of injection, which would vary in each case with the force of propulsion, we should expect to find that the resistance offered by the dioritic rock would overcome the piercing power of the granite.

The process of injection was doubtless aided by the partial plasticity of the dioritic rocks—a plasticity induced probably by the neighbourhood of igneous masses, for it seems to have been local in its development. It would also have been aided in the case of consolidated ash-beds—especially in submarine ash-beds—by the planes of sedimentation, and in the case of diorite intruded as sheets by the foliation developed in a direction parallel to the bedding. The existence of such planes of weakness would explain why the injected granite displayed a tendency to follow lines parallel to the bedding, and in doing so produced the superficial appearance of banding.

The remarks offered under the head of hornblende-schists on the application of the hypothesis of deformation to the explanation of the fine banding of those rocks apply generally to the banding of the "granulitic" series and need not be repeated. Suffice it to say that I have not observed anything in the microscopic structure of the rocks under description to support the application of the deformation-hypothesis to the "granulitic" group. The quasi-banding described is consistent with the theory of injection; but I do not see that it can be reasonably accounted for by any process of deformation.

Figs. 8 and 9 are woodcuts of two hand-specimens from Kildown Cove *. Had I been able to take photographs of rocks *in situ*, more striking illustrations might have been given, but figs. 8 and 9 may be accepted as fair samples of the structure under description.

In the case of injections into the porphyritic diorite the thin veins of granite are deflected from their course by the porphyritic crystals. In one instance I found that the felspar that had deflected a vein was about three inches long, and it was orientated nearly at right angles to the vein (as shown in fig. 10), an incidental proof, it seems to me, that the veining was not produced by dynamic deformation. The shearing or crushing that could have reduced a lump of granite to an attenuated string would have crushed the felspar to a flat wafer.

Mr. Teall, in his paper already quoted from the 'Geological Maga-

* One of these illustrations was photographed on the block; in the case of the other this process could not be employed, owing to the red tint of the granitic veins.

Fig. 8.—*Hand-specimen of "Granulite," Kildown Cove.*

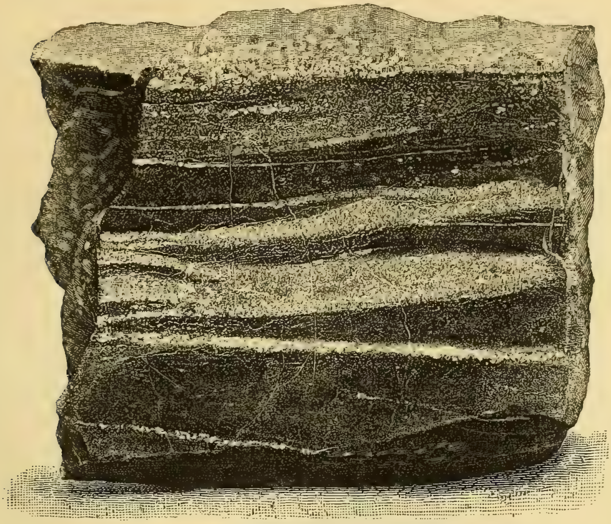
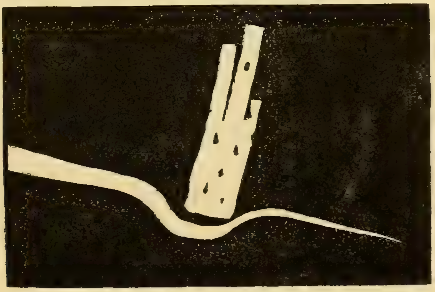


Fig. 9.—*Hand-specimen of "Granulite," Kildown Cove. Granitic veins in porphyritic diorite.*

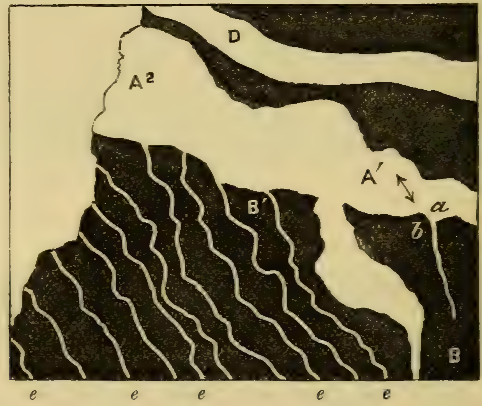
Fig. 10.—*"Granulite," Kildown Cove. Granitic vein deflected by a porphyritic felspar.*



zine,' has given a photograph of a portion of an intrusive vein in a cliff at Pen Voose. As I desire to note one or two important facts not heretofore brought to notice regarding this vein, I give a rough sketch of it below. The veins shown at *e e e* are very thin and very numerous*. The "granulite" here is a holocrystalline diorite, but I was not able to discover any break between it and the rocks of the "granulitic" group which show in force in this cove.

I may observe in passing that the granite is distinctly foliated at A^1, but the foliation dies out towards A^2. The direction of the foliation is indicated by a double arrow. Some of the fine veins are also foliated, the foliation being parallel to their sides. Now the point to be noted is that the dioritic rock (B^1, B) and the gabbro

Fig. 11.—*Intrusive Vein in Cliff at Pen Voose.*



at D give no indication of foliation either in the field or under the microscope. I have examined specimens of the granite taken from *a*, and of the diorite taken from the point marked *b*—the places being only a few inches apart—but though the granite is very distinctly foliated, the diorite does not show the slightest trace of this structure †. This fact has, I think, an important bearing on the question of the foliation of the Lizard rocks. We need not go further than the Lizard to learn that diorite and gabbro put on foliation with great ease—more readily, probably, or at any rate as readily, as granite—and that being so the fact that the granite is foliated, but the diorite and gabbro on either side of it are not foliated, seems to me to lead to the unavoidable conclusion that the foliation of the granite was produced prior to its perfect consolidation. The granite was the last of the three eruptive rocks to appear, and had

* The exigencies of a small woodcut necessitated their being reduced in number and increased in relative thickness.

† The foliated granite alluded to will be found under Nos. 20, 21 of the "granulitic" group table (p. 532), and the diorite taken from (*b*) under No. 12 of the same list.

the foliation of the granite been produced by pressure after it had completely cooled, the diorite and the gabbro could not possibly have escaped putting on a foliated structure. If the thin veins of granite yielded, why not the diorite between them?

At Holestrow, and north-west of Pentreath Beach, the rocks that crop up on the sea-shore are, I think, as suggested by Messrs. Fox and Somervail in their paper read before the British Association in 1887, a part of the "granulitic" group. They certainly resemble the rocks of this group very closely and they occur here, and further on near the Lion rock, in their normal position * next the serpentine—facts that cannot be alleged of the dykes of intrusive rocks in serpentine at North Pentreath, which are also claimed by Mr. Somervail as a portion of this group. At North Pentreath, where the serpentine cliffs touch the shingle of the beach, at the east side of the chine, the serpentine is cut through by several veins of intrusive diorite, which pierce it in various directions, but, at least, one of which strikes up the hill. These veins are cut across by a strong vein of granite (here very felspathic), which after running a course approximately parallel to the sea-shore also turns upwards towards the main dyke of granite described by Prof. Bonney in his first paper †. These veins of granite and diorite do not intermingle. Higher up, where the granite appears in force, it contains at least one included block of diorite—a block so sharply angular that its character can hardly be mistaken. A little above this there is a mass of diorite, one side of which is buried under grass, of which it is difficult to say whether it is a collection of transported blocks, or whether the granite in its upward course impinged against the side of a dyke of diorite. Whichever be the true explanation, one point is perfectly clear, namely, that the granite is younger than the diorite, for the latter is penetrated by very numerous tongues and veins of the former. At this point the granite disappears, but the diorite reappears further up the hill-side as a thickish vein in serpentine.

The space that intervenes between these dykes of intrusive rocks and the outcrops of the "granulitic" group is covered by shingle and boulders, and no direct connexion is to be made out between them. These dykes do not resemble the "granulitic" group, as they are not banded. We have at North Pentreath simply an example of what I have very often seen in the Himalayas, namely, of granite following the course of a dyke of eruptive diorite for a short distance.

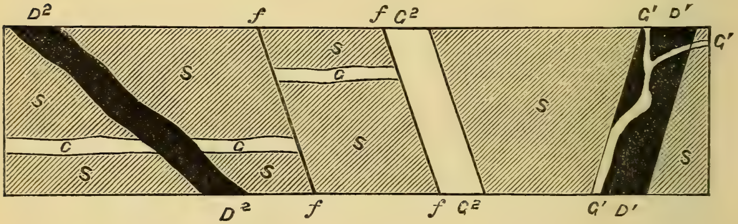
At Kennack Cove the facts are very similar to those of North Pentreath. In the illustration given below (fig. 12) I have depicted two dykes of diorite (D^1, D^2) and two dykes of granite (G^1, G^2) intrusive in serpentine. The sketch represents diagrammatically a section of the serpentine cliffs on the sea-shore at the west end of the cove. G^1 is about ten yards distant from G^2 at the base of the cliff. Could we trace the course of the diorite-dykes (D^1, D^2) downwards we should probably find that they constituted the two bifurcations of one

* I do not mean by this expression to indicate their geological sequence, only that in the field they are commonly found next the serpentine.

† Quart. Journ. Geol. Soc. xxxiii. p. 887.

dyke. Similarly the two granite dykes (G^1, G^2) had probably an underground connexion with each other at the time of eruption. This, however, is a mere matter of inference, as owing to shingle and boulders on the sea-shore (not to mention the two faults) their onward course cannot be traced, nor can they be directly connected with the outcrop of the "granulitic" group on the foreshore.

Fig. 12.—*Diorite- and Granite-dykes intrusive in Serpentine, Kennack Cove.*



S, serpentine; *c*, *c*, gabbro; D^1, D^2, diorite; G^1, G^2, granite; *f*, *f*, faults.

At G^2, D^2 we see the diorite and granite running separate courses through the serpentine; at D^1, G^1 the granite has followed the diorite, and for a short distance they have held a common course. This circumstance, taken alone, is insufficient to justify our calling D^1, G^1 an intrusive dyke of "granulite."

Mr. Somervail states that at the west end of Kennack Cove "the dykes cutting the serpentine are seen to coalesce with the 'granulitic' rocks forming the foreshore." My last visit to the cove was made at a time particularly favourable for observation. It was at low water at spring-tide, and recent storms had swept away accumulations of sand and shingle to such an extent that Mr. Fox saw for the first time rocks *in situ* that on every previous visit had been buried six feet deep under sand. I saw that the porphyritic diorite had intruded profusely into ordinary diorites (presumably the dioritic rocks of the "granulitic" group) and that both had been invaded and injected by intrusive granite. Granite-veins may be seen darting about in all directions, crossing and recrossing each other at every angle, in the porphyritic diorite of the foreshore; but I could not directly connect the diorite and granite of the foreshore with the diorite and granite of the serpentine-cliffs. The question then arises, Are they portions of the same intrusions, or do the diorite and granite in the cliffs represent intrusions of one period, and the diorite and granite in the "granulitic" group on the foreshore those of another age? This question will best be answered after the consideration of two other sections.

On the occasion of my last visit I was able, thanks to Mr. Fox's able guidance, to reach a very interesting spot, only exposed for a short time at spring-tide, on the west coast, about 200 yards east of

the Lion Rock, near the mouth of Penzance Cove. No one, I may say, should attempt to visit this spot without a competent guide, for the ground is laborious and somewhat difficult to get over: the cliffs are not to be scaled; and a stranger might run considerable danger of being cut off by the tide.

The "granulitic" group is well seen in this neighbourhood, and a study of it here is sufficient to show that the quasi-banding seen in it (which closely resembles that of the normal "granulite") is due to the injection of granite. Under Yellow Carn, about 160 yards from the Lion Rock, a dioritic rock turns sharp up the cliff and apparently emanates from the "granulitic" rocks seen hard by (the actual junction is, I believe, masked by huge boulders). This dyke-like mass appeared to me to be a dioritic portion of the "granulitic" group, nipped between two converging masses of intrusive serpentine; but it is important to observe that the dioritic rock does not exhibit banding. Near the junction of this dioritic rock and the serpentine I observed several lumps of serpentine that looked like truncated tongues. Two of these I was able to trace up to within half an inch of the serpentine, from which they were separated by a vein of fibrous serpentine which, to all appearance, has been formed by infiltration along a joint. There is, however, so much difficulty in distinguishing between an intrusive diorite (when non-porphyritic) and dioritic portions of the "granulitic" group that I could not feel certain whether these lumps of serpentine were tongues or blocks.

Similar blocks occur in the banded series on the east coast, about 200 yards north of the Cavouga rocks. Here the banding is, on the whole, more regular than usual, but the dioritic portion appears to consist wholly of the porphyritic diorite. The porphyritic crystals are small, but they are pretty generally disseminated through it. The blocks of serpentine alluded to are to be observed in this diorite next a mass of serpentine; they vary in distance from it from two inches to two feet, and I could find no instance in which they are actually connected with it. We have already seen that the porphyritic diorite gives evidence at Polpeor and elsewhere of being a truly intrusive rock. Within a few yards of these blocks of serpentine in the porphyritic diorite the latter appears as an intruder in the serpentine *, and the conclusion seems inevitable that here, at all events, the blocks of serpentine are not truncated veins, but are true inclusions in eruptive diorite. It is material to note further that the thin bands of granitic matter in the diorite are bent at their points of contact with these boulders. This seems to be quite analogous to the cases, mentioned in the preceding pages, where these granulitic veins are deflected by the porphyritic crystals in the diorite, and both facts, taken in connexion with the evidence supplied by the Kennack foreshore, show that the porphyritic diorite was injected with granite after its intrusion into the "granulitic" group.

* These dykes are described in Messrs. Fox and Somervail's paper referred to *ante*.

The facts seem to lead naturally to this conclusion, and I do not see how it can be avoided.

This being so, the further inferences seem natural that the eruptions of diorite and granite in the cliff at Kennack Cove belong to the same period as the intrusions of diorite and granite into the rocks on the Kennack foreshore, and that the injection of the dioritic rocks at Kennack Cove, in the form of quasi-banding, took place during the same period.

If the rocks of the "granulitic" group at Kennack Cove and Cavouga were injected with granite subsequent to the intrusion of the porphyritic diorite, the same conclusion holds good for those on the sea-shore at Holestrow, Pentreath, and under Yellow Carn; but the question remains whether the bedded "granulite" at Pen Voose and in that neighbourhood ought not to be separated from them, and whether both series, viz. the Pen-Voose "granulites" and the Kennack and Holestrow rocks of "granulitic" aspect, were injected with granite during the same or at different periods. On these points I think it prudent to suspend judgment for the present. There are several matters connected with these questions that require elucidation. Faults are so abundant along the coast of the Lizard that the apparent relation of the "granulitic" rocks to the hornblende-schists differs materially in different places.

One more exposure requires to be briefly noted. At the north end of Kildown Cove three strips of the "granulitic" group are to be seen in serpentine cutting across the root of the Eny's Head under circumstances that give colour to Mr. Somervail's theory that the "granulitic" rocks have intruded into the serpentine. Prof. Bonney's explanation of this section is that the serpentine is intrusive in the "granulitic" group. My own view is that the position of the "granulitic" rocks here is due to faulting. The more westerly of the three strips has the appearance of being faulted against the serpentine; for a broad dyke of gabbro that strikes at the "granulite" at a high angle ends sharply at the "granulite" and does not reappear in the serpentine on the other side, which it would surely do if the "granulite" had been erupted through the serpentine and its contained gabbro. The natural inference is that the gabbro is cut off by a fault.

Discussion.

The President noticed the revival of Bischof's views. The supposed ash-beds the late David Forbes was perhaps right in considering had been produced by lava issuing into water.

Dr. Geikie would be reluctant to accept the Author's conclusions. Though he had not examined the ground, he could not believe that the rocks there had escaped from the deformation which was so manifest throughout Cornwall.

Mr. Teall commented on the complexity of the subject. The district had been examined by Dr. Bonney, and subsequently by himself, and although on some points the Author reconciled the

differences between Prof. Bonney and himself, he had also differed from both, though perhaps agreeing more with Prof. Bonney. The paper followed one read at a previous meeting, where foliation was actually taken as evidence of deformation. The absence of mechanical crushing in the crystals of a rock could not, he believed, be taken as evidence that the rock was not due to the deformation of a preexisting rock. Referring to the Scourie dyke, he observed that it yielded absolute proof of a holo-crystalline schist produced by the deformation of a preexisting crystalline rock. With regard to the Author's speculations as to the banding of the crystalline schists of the Lizard, he must confess that he was unable to follow them. As to the origin of the series as a whole, he wished to remain neutral for the present. The granulitic group supposed by Dr. Bonney to be a sedimentary series is considered by the Author to be sedimentary with intrusions. He thought no further advance could be made on this point until the supposed two series had been mapped. In a paper he had written elsewhere on the origin of banded gneisses, he had referred to the granulitic series, and he was not disposed to modify his view from what he had heard. The granitic and dioritic rocks of the series exhibit indubitable igneous relations in places, whilst in other places they occur as parts of a banded gneissic series. In the banded rocks there are appearances strongly suggestive of fluxion, and he had proposed that the banding was the result of the deformation of a heterogeneous mass whether before or after consolidation, and had illustrated his views by experiments. There was no limit to the fineness of the banding produced by deformation. He believed that when the truth was fully out, it would be found that everyone who had worked at the district had contributed towards it.

Prof. Bonney had examined the schists at an unfortunate epoch, and he had consequently fallen into one error. Amongst the banded series occurred porphyritic felspar, which he now knew was usually indicative of an igneous origin, and he had overlooked several masses which he would now be inclined to regard as igneous. But after reexamination he was by no means clear as to whether the general metamorphic origin of the Lizard rocks can be given up, though there is certainly much igneous material therein. Mr. Teall had spoken of the association of granite and diorite in two ways, as if the rocks occurring in the one case massive, in the other foliated, were of the same age; he was not certain about this identity. He still thought that in the granulitic series there were rocks very difficult to explain, on the view that they are merely crushed-out igneous rocks, though what their origin was he was unprepared to say. He knew them in other parts of the world, and was not satisfied with the dynamic-deformation explanation. We have to explain a process curiously imitative of sedimentation. He did not think Mr. Teall's experiments quite reproduced the conditions occurring in nature. In regard to both the granulitic and the hornblendic series his difficulty was to account not for the fine, but for the broad banding on the mechanical deformation theory. He exhibited

a specimen in illustration of this. As to whether the explanation the Author gave was actually correct, he was doubtful. He did not expect to find malacolite in an ordinary basic rock. Moreover, though the mineral augite is unstable, he doubted if its position was unstable. Although he believed that much of the Lizard rock was sedimentary, he was not prepared to accept concentration of material into bands as the Author suggested. He felt sure, however, that the Society would thank the Author for the very clear way in which he had put his facts and views before them, because on so difficult a subject all well-considered hypotheses would tend to the discovery of truth.

Mr. Rutley thought that in the case of felspar-crystals lying at right angles to the planes of foliation and also in some other cases, the Author had brought serious difficulties in the way of those who accepted theories of mechanical deformation. In the granulitic series there appeared to have been something resembling selective foliation. He believed that water did play an important part in the production of schists.

Dr. Hicks asked how the Author got rid of all movement in such an area as the Lizard. He thought it was far more likely that some of the results referred to were due to deposition along lines of cleavage than to sedimentation; such lines of cleavage showing movement certainly occurred in this region. He thought the supposed granite-vein in the diagram exhibited (fig. 11) might possibly be due to secondary segregation.

The Author remarked, in answer to Dr. Hicks's observation, that the granite was an eruptive vein which had been photographed by Mr. Teall, and the eruptive nature of which, he thought, no one doubted. The finer parallel streaks he considered to be also eruptive.

With reference to what Prof. Bonney said, he did not wish to suggest that the augite crystals moved about the rock, but that the substance was carried in solution and re-deposited, and this he held was proved by the fact that in certain cracks hornblende had been deposited from water. Commenting upon the objections raised by Dr. Geikie and Mr. Teall, his opposition to the theory of dynamic deformation was a protest against every case of foliation being given as an instance of dynamic deformation.

34. *The* Upper Jurassic Clays *of* Lincolnshire. By Thomas Roberts, Esq., M.A., F.G.S., Woodwardian Museum, Cambridge. (Read May 22, 1889.)

Contents.

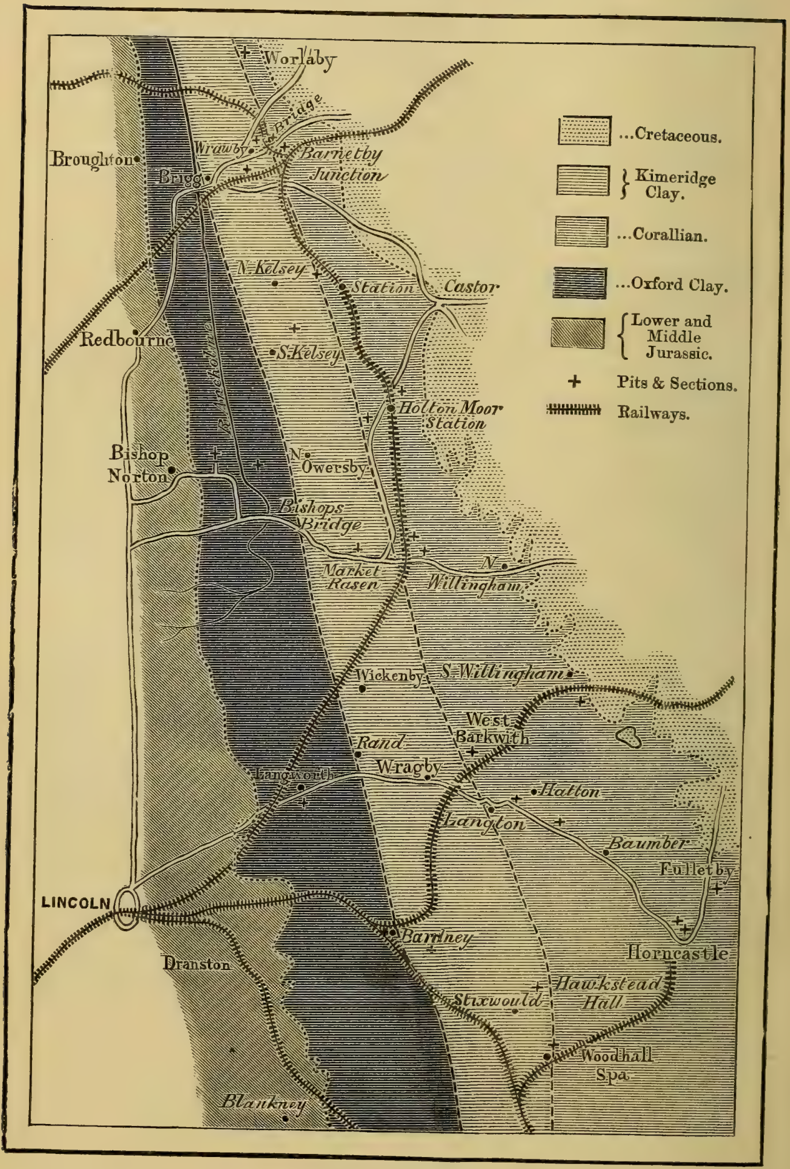
1. Introduction.

The broad tract of low country which extends from the Humber through the middle portion of Lincolnshire, and spreads out into the fen-country to the south, is underlain by a thick deposit of clay which, in the adjoining county of Cambridgeshire, has been called the "Great Fen-Clay"*. The lower portion of this great pelolithic formation is undoubtedly of Oxford-Clay age, whilst its upper portion certainly belongs to the Kimeridge Clay. Owing to the absence of beds lithologically resembling those of the Corallian rocks of Yorkshire and the southern and south midland counties of England, no division corresponding in age to the Corallian has as yet been made out in Lincolnshire.

Prof. Blake states that the Kimeridge and Oxford Clays here form one continuous formation †. In the Survey Memoir on this district it is mentioned ‡ that the Corallian group is entirely absent, and only the Oxford and Kimeridge Clays are mapped. Jukes-Browne goes still further, and states that "in Lincolnshire there is nothing to represent the Corallian group, the Oxford Clay merging gradually into the Kimeridge Clay" §. H. B. Woodward mentions that in Lincolnshire, Buckinghamshire, Norfolk, and probably Sussex, "the Kimmeridge and Oxford Clays come in direct sequence," and he adds that "unless we imagine an unconformity—and there is no reason for this supposition—the Coral Rag and Calcareous Grit developed in Oxfordshire, Wiltshire, and Dorsetshire, are represented by portions of the Oxford and Kimmeridge Clays in the districts just mentioned" ||. No attempt, however, has as yet been made to separate off a portion which would be equivalent to the Corallian of other areas.

* 'Seeley,' Geologist, vol. ii. p. 552.
† Blake, Quart. Journ. Geol. Soc. vol. xxxi. p. 216. See also Woodward's 'Geology of England and Wales,' 2nd ed. p. 329.
‡ Mem. Geol. Surv. sheet 83, p. 73.
§ 'Historical Geology,' p. 353.
|| Proc. Geol. Assoc. vol. iv. p. 266.

Fig. 1.—*Map of part of Lincolnshire.* (Scale $\frac{1}{6}$ in. to 1 mile.)



In 1862, Professor Seeley * divided the "Fen-Clay" of Cambridgeshire into :—

1. Kimeridge Clay.
2. Ampthill Clay †, which he regarded as Corallian.
3. Oxford Clay.

The Ampthill Clay rests on the Elsworth Rock, which was considered by Seeley to be "the uppermost zone of the Oxford Clay." He states that "the upper boundary of the Tetworth [Ampthill] Clay cannot be given with any certainty" ‡.

In the Sedgwick Essay for 1885, it is shown that (1) the Elsworth Rock is of Lower-Calcareous-Grit age, (2) the basement-bed of the Kimeridge Clay contains numerous phosphatic nodules, which give a well-defined upper boundary to the Ampthill Clay. The succession in the Upper Jurassic Clays of Cambridgeshire is, therefore, as follows :—

1. Kimeridge Clay with a phosphatic-nodule bed at its base.
2. Ampthill Clay, together with the Elsworth Rock, representing the Corallian.
3. Oxford Clay.

During the past summer the various clay-pits and sections marked on the accompanying map (fig. 1) were visited with a view of ascertaining whether any clays corresponding to the Ampthill Clay occur in Lincolnshire between the Oxford and Kimeridge. Particular attention was given to those exposures which are situated in the upper part of the Oxford Clays, and the lower portion of the Kimeridge Clays shown in the Survey Map (sheet 83) and Blake's sketch map (*op. cit.* p. 202). It is proposed in this paper to give the results obtained during that visit.

The portion of Lincolnshire occupied by these Jurassic Clays is more or less completely covered by drift, and the only places where sections can be seen in the clays are the various clay-pits, and occasionally in the railway-cuttings. Further, some of the drifts are largely made up of Jurassic Clays, which are not in place, because they contain fragments of chalk and other rocks. Sometimes these glacial clays are fossiliferous, and great care has to be taken that the fossils obtained in any locality come from the undisturbed clay, and not from the drift.

2. The Oxford Clay.

The general character of the Oxford Clay of Lincolnshire is that of a dark blue clay, with pyritized fossils and nodules of iron pyrites §. Morris || describes the basement beds in the Casewick Cutting, where he recognizes the Kellaways Rock; a more complete account of this subdivision is also given in the Survey Memoir ¶.

* Ann. Mag. Nat. Hist. 3rd ser. vol. x. p. 101.

† This clay has also been called the Bluntisham, Tetworth, and Gamlingay Clays.

‡ Geologist, vol. iv. p. 553.

§ Mem. Geol. Surv. sheet 83, p. 76.

|| Quart. Journ. Geol. Soc. vol. ix. p. 333.

¶ Sheet 83, p. 73.

In Rutlandshire and the southern part of Lincolnshire, Prof. Judd * recognizes the following zones in the Oxford Clay :—

6. Clays with Ammonites of the group of the *cordati*.
5. Clays with Ammonites of the group of the *ornati*.
4. Clays with *Belemnites hastatus*.
3. Clays with *Belemnites Owenii*.
2. Clays with *Nucula*.
1. Kellaways Rock.

Five of these zones are stated to occur in south-west Lincolnshire †, the sixth (uppermost) being concealed by drift.

The pits at Bardney, Langworthy, Bishop's Norton, and south of Peaseholme were visited by the author, but the Oxford Clay may also be seen in several other localities. The most important sections are the following :—

Immediately to the north of Bardney Station dark blue clays are worked for brick-making. These clays have yielded the following fossils :—

Plesiosaurus (phalanges).
Ichthyosaurus (vertebra).
Ammonites cordatus, *Sow.*
—— Eugenii, *Rasp.*
Cerithium muricatum, *Sow.*
Pinna, sp.
Gryphæa dilatata, *Sow.*
Serpula sulcata, *Sow.*
—— tricarinata, *Sow.*

The following Ammonites ‡, now in the Jermyn Street Museum, are also recorded § from this locality :—

Ammonites perarmatus, *Sow.*
—— excavatus, *Sow.*
—— biplex, *Sow.*
Ammonites macrocephalus, *Sow.*
—— arduennensis, *D'Orb.*
—— plicatilis, *Sow.*

Most of the Bardney fossils are characteristic of Judd's zone of *cordati* Ammonites. They are also found in the uppermost zone of the Oxford Clay of Huntingdonshire.

* Geology of Rutland, &c. (Mem. Geol. Surv.), p. 232.

† Geology of S.W. Lincolnshire (Mem. Geol. Surv.), p. 70.

‡ Some doubt having been expressed as to the correct determination of these fossils, I have taken the opportunity, since the paper was written, of closely examining them.

The two first-named species in the list are correctly given.

The specimen from which *Amm. biplex* is named consists of a portion of two whorls. The whorls are round, and one of them shows a well-marked constriction. Each of the primary ribs is divided into two or three secondary ones, and the latter are considerably smaller than the former. This distinguishes it from *Amm. biplex*, where the divided and undivided ribs are equally thick. The specimen is near to, if not identical with, *Amm. convolutus dilatatus*, Quenst.

The so-called "*Amm. macrocephalus*" shows the back and a portion of one side of the outer whorl only, and this is very much crushed. The primary ribs are less numerous than in a typical example of this species, and are more nearly allied to those of a mature *Amm. mariæ*. The specimen is, however, too badly preserved for correct determination.

The remaining species (*Amm. arduennensis* and *Amm. plicatilis*) may be correctly named, but the specimens are badly preserved, and do not show sufficient characters to identify them with any degree of certainty.

§ Surv. Mem. sheet 83, p. 77.

Clays similar to those of Bardney are stated to occur * in the valley near Rand, about five miles north of Bardney.

At the Langworthy brickyard is a small exposure of dark clays. These had not been worked for some time, and fossils were not abundant, but the following were obtained here :—

Ammonites cordatus, *Sow.*	Alaria bispinosa, *Phill.*
—— Eugenii, *Rasp.*	Avicula Muensteri, *Goldf.*
—— hecticus, *Röm.*	Gryphæa dilatata, *Sow.*
†—— Lamberti, *Sow.*	

Further north, a short distance east of the village of Bishop's Norton, dark clays occur, containing *Belemnites Owenii* in abundance, together with :—

Ichthyosaurus (vertebræ).
Cerithium muricatum, *Sow.*
Gryphæa dilatata, *Sow.*

The occurrence of the first-named fossil in such large numbers, places these clays in zone 3 of Prof. Judd, *i. e.* clays with *Belemnites Owenii.*

About 1½ mile east of the last-mentioned pit (½ mile south of Peaseholme on Survey Map) is another brickyard showing dark blue clays, from which were obtained *Belemnites hastatus*, Montf. (common), a small pyritized Ammonite, and *Gryphæa dilatata*, Sow. This pit is on the horizon of Judd's zone 4.

Clays belonging to a somewhat higher horizon (zone of *ornati* Ammonites) were met with in a well-boring west of Bishop's Bridge. The following fossils are recorded ‡ from here :—

Ammonites plicatilis.	Ammonites Duncani.
—— hecticus, *var.* canaliculatus.	—— Lamberti.

The Oxford Clay is also worked in the brickyard ½ mile north-east of Timberland Church, Snarford Hill, and ½ mile east of Normanby Church §.

The clays in the above-mentioned sections appear, from their fossils, to belong to four of the zones recognized by Prof. Judd in South Lincolnshire, and may be arranged as follows in descending order:—

4. Clays with *cordati* Ammonites (Bardney and Rand)=Judd's zone 6.
3. Clays with *ornati* Ammonites (Bishop's Bridge)=Judd's zone 5.
2. Clays with *Belemnites hastatus* (south of Peaseholme)= Judd's zone 4.
1. Clays with *Belemnites Owenii* (Bishop's Norton)=Judd's zone 3.

Further west, the Kellaways Rock has been recognized in several localities ||.

* Survey Mem. sheet 83, p. 77.
† In Jermyn Street Museum.
‡ Survey Mem. sheet 83, p. 78.
§ Survey Memoir, sheet 83, p. 77.
|| *Ibid.* pp. 75–76.

3. The Clays above the Oxford Clay.

(a) *General Description.*

Overlying the Oxford Clay, with its pyritized Ammonites, is a series of clays varying somewhat in their lithological character as well as in their fossils. The clays *up to the summit of what has been mapped as Lower Kimeridge* may be conveniently divided into four zones. The *lowest* of these is made up of black clays, which usually contain numerous well-developed crystals of selenite. The fossils are, as a rule, not abundant, but it will be seen that they differ from those in the clays above and below, although several species are common to all three.

The black clays were nowhere seen immediately overlying the Oxford Clay, but they are found in several places to the east of what is regarded as the uppermost zone of the Oxford Clay (zone of *cordati* Ammonites). They are easily distinguished from the latter by their darker colour, and by their fossils never being pyritized.

The most southerly point at which these clays were seen is in a brickyard west of Hawkstead Hall, where there is exposed 17 feet of black clays containing numerous crystals of selenite, either scattered through the clays or aggregated in masses held together by a yellowish ferruginous material. The clays here were unfossiliferous, but in the layer of septarian nodules which occurs in the upper part of the section, *Ammonites excavatus*, Sow., was not uncommon. Prof. Blake also records from this pit *Ostrea deltoidea* and *Belemnites nitidus* *.

About half a mile south-east of the village of Bardney (at "C" in "Bardney Common" on Survey Map) is a brickyard in which are black shaly clays with minute crystals of selenite. The following fossils are fairly common here:—

Belemnites abbreviatus, *Mill.*
—— nitidus, *Dollf.*
Gryphæa dilatata, *Sow.*

In addition to which the following are recorded in the Survey Memoir †:—

Thracia depressa, *Sow.*
Cucullæa longipunctata, *Blake.*
Astarte supracorallina, *d'Orb.*

In the Jermyn Street Museum are some badly-preserved Ammonites from this locality, some of which appear to belong to

Ammonites vertebralis, *Sow.*
—— cawtonensis, *Bl. & H.*

Further north, Prof. Blake mentions ‡ that in a well-sinking on the Bishop's-Bridge road, about $1\frac{1}{2}$ mile west of the Market-Rasen pits, black clays were met with in which *Belemnites nitidus* and *Gryphœa dilatata* were plentiful, together with some reptilian remains and *Discina Humphriesiana.*

* *Op. cit.* p. 209. † P. 79. ‡ *Op. cit.* p. 209.

In a brickyard north of South Kelsey may be seen 15 feet of black clays containing numerous crystals of selenite; near the floor of the pit is a layer of septarian nodules from which the majority of the following fossils were obtained:—

Ammonites plicatilis, *Sow.*
—— decipiens, *Sow.*
Alaria bispinosa, *Phill.*
Avicula pteropernoides, *Bl. & H.*
Pecten fibrosus, *Sow.*
Gryphæa dilatata, *Sow.*
Ostrea bullata, *Sow.*
Pholadomya concentrica, *Röm.*
Rhynchonella, nov. sp. (near to subvariabilis).

Similar clays are exposed in a brickyard about half a mile west of North Kelsey station, which yielded the following fossils:—

Ichthyosaurus (vertebræ).
Ammonites achilles, *d'Orb.*
—— plicatilis, *Sow.*
Belemnites abbreviatus, *Mill.*
Alaria bispinosa, *Phill.*
Cardium striatulum, *Sow.*
Thracia depressa, *Sow.*
Astarte supracorallina, *d'Orb.*
Cucullæa contracta, *Phill.*
Avicula, sp.
Pinna lanceolata, *Sow.*

In the first railway-cutting east of Brigg are black clays with some septarian nodules and a few selenite crystals. *Gryphæa dilatata* is very common in these clays, from which also the following fossils were obtained:—

Ammonites cordatus, *Sow.*
Alaria bispinosa, *Phill.*
Rhynchonella, nov. sp. (near to subvariabilis).
Serpula tricarinata, *Sow.*

Prof. Blake also records nine species from this cutting *.

Further north, in the western half of the Wrawby-Bridge cutting, are black clays very rich in selenite. The clays are much weathered, but the following fossils were obtained here:—

Ostrea deltoidea *Sow.*
Rhynchonella, nov. sp. (near to subvariabilis).
Serpula, sp.

Another cutting, about $\frac{1}{4}$ mile north-west of the last mentioned, shows precisely similar clays, with some septarian nodules, which yielded the following fossils:—

Ammonites achilles, *d'Orb.*
Ostrea deltoidea, *Sow.*

Prof. Blake also mentions the occurrence here of *Gryphæa dilatata*, *Belemnites nitidus*, and six other species †.

He also quotes ten species from Wrawby ‡, which, from its position, should be on the horizon of these selenitiferous clays. At the present time, however, no section is visible near this village except those in the above-mentioned railway-cuttings.

Leaving aside the consideration of the age of these clays for the present, we pass on to a description of the clays which succeed them. This *second* zone is characterized by the presence of *Ostrea deltoidea* in abundance.

* *Op. cit.* p. 206. † *Op. cit.* p. 209. ‡ *Op. cit.* p. 207.

The clays in the brickyard (which is now closed) north of Woodhall Spa lie a little to the east of the line of strike of the selenitiferous clays of Hawkstead Hall. Professors Blake * and Judd † describe the clays of Woodhall Spa as being full of *Ostrea deltoidea*, associated with *Ammonites serratus* (=*alternans*), *Belemnites nitidus*, &c. The clays in the brickyard west of Barkwith (now closed) are stated by Blake to possess multitudes of fragments of oysters ‡. Further north, in the brickyard ¾ mile south of Holton-le-Moor station, are dark clays with :—

Ammonites decipiens, *Sow.*	Ostrea gibbosa, *Les.*
Corbula fallax, *Cont.*	Anomia Dollfussii, *Blake.*
Ostrea deltoidea, *Sow.*	Serpula tetragona, *Sow.*

At the brickyard mentioned above as occurring ½ mile west of North Kelsey Station, the workmen informed me that when the pit was first opened, a short distance to the east of where they are now at work, the clays were so full of oyster-shells (like *O. deltoidea* pointed out to me) that they proved useless for brickmaking. If the observation of these men can be regarded as trustworthy, we appear to have at this point clays similar to those of West Barkwith and Woodhall Spa.

The selenitiferous clays of the Wrawby-Bridge railway-cutting mentioned above are succeeded by dark clays with brownish ironstone concretions and some nodules of iron-pyrites. They may be seen on the east side of the bridge, but their junction with the underlying clays cannot be seen, because it is concealed by *débris*. These clays are much weathered and fossils are not abundant; nevertheless, *Ammonites decipiens* is fairly common, as well as *Thracia depressa* and *Astarte supracorallina*. Prof. Blake also records § *Ammonites biplex*, *Cerithium cerebrum*, *Nucula Menkii*, and *Serpula tetragona*.

A brickyard at the south end of the village of Worlaby is opened in dark blue somewhat sandy clay, with brownish ironstone concretions and some iron-pyrites. The following fossils were obtained here:—

Ammonites decipiens, *Sow.*	Phaladomya acuticosta, *Sow.*
Cerithium forticostatum, *Blake.*	Ostrea gibbosa, *Les.*
Arca, sp.	Serpula intestinalis, *Phill.*

Prof. Blake mentions ‖ the occurrence in this pit of *Lingula ovalis* and *Ammonites biplex*. He considers the clays of Worlaby to be the lowest beds of the Kimeridge Clay observed in Lincolnshire, and places them below the selenitiferous clays of Wrawby-Bridge cutting, and also of that to the north-west of the latter. Lithologically, however, they are identical in character with the clays seen in the eastern half of the Wrawby-Bridge cutting. The most common fossil present in both is *Amm. decipiens*, and these are preserved under similar conditions ; ironstone concretions and iron-pyrites, not noticed elsewhere in the Kimeridge Clay of Lincoln-

* *Op. cit.* p. 210. † Quart. Journ. Geol. Soc. vol. xxiv. p. 240.
‡ *Op. cit.* p. 209. § *Op. cit.* p. 206. ‖ *Op. cit.* p. 210

shire, are found in both localities. Further, the fossils of the clays of Worlaby assign them to a higher horizon than the selenitiferous clays.

From the above observations it will be seen that the selenitiferous clays are succeeded in the southern part of the district under consideration by clays containing *Ostrea deltoidea* in abundance; whilst further north, and probably at a slightly higher horizon, there occurs a band of clay with ironstone concretions and iron-pyrites, in which *Amm. decipiens* is fairly common.

The *third* zone includes the clays in the pits of Baumber, Langton, Market Rasen, and Holton-le-Moor Station, all of which have been fully described by Prof. Blake *. There is but little to add to his account of these sections. The clays in the brickyard ½ mile west-south-west of Hatton (called Langton by Prof. Blake) yielded the following species in *addition* to those recorded by him :—

Ammonites decipiens, *Sow.*
Cerithium multiplicatum, *Blake.*
Anomia, sp.
Ostrea gibbosa, *Les.*
—— læviuscula, *Sow.*
Arca longipunctata, *Blake.*
Pholadomya acuticosta, *Sow.*
—— Protei, *Ag.*
Pholadidea compressa, *Sow.*
Cardium striatulum, *Sow.*
Corbula fallax, *Cont.*
—— Deshayesia, *Buv.*

The fauna of the clays of Langton presents a close affinity with that of Market Rasen and also of Baumber. *Ammonites alternans*, which is very rare in the clays below, is very common in this zone, and may be regarded as its characteristic fossil. The fauna is much richer than that of any other zones of the Kimeridge Clay, over 50 species being recorded from the above-mentioned localities alone.

The *fourth and uppermost* zone of these clays is that which occurs in pits near Horncastle †. At present only two pits are open, and these show dark clays with septarian nodules. These clays are distinguished from those of the underlying zone principally by the absence in them of *Amm. alternans*, and also by the fossils being less numerous and badly preserved.

The clays occurring between the Oxford Clay and Upper Kimeridge in Lincolnshire may be divided therefore into the following four zones, arranged in descending order :—

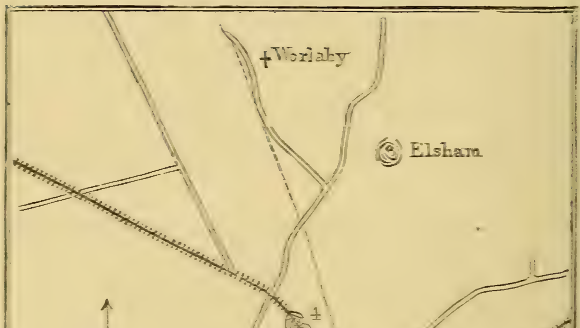
4. Clays with Lower Kimeridge fossils, in which *Amm. alternans* is absent.
3. Clays in which *Amm. alternans* is common.
2. Clays crowded with *Ostrea deltoidea.*
1. Selenitiferous clays with *Ostrea deltoidea* and *Gryphæa dilatata.*

Nearly the whole of these four zones of clays has been mapped by Prof. Blake ‡ and the Geological Survey § as Lower Kimeridge. Prof. Blake subdivides his Lower Kimeridge of Lincolnshire into six zones, but his arrangement differs somewhat from that adopted in this paper. The clays in the cutting east of Brigg are regarded

* *Op. cit.* pp. 207, 208.
† Blake, *op. cit.* p. 205.
‡ *Op. cit.* p. 202.
§ Sheet 83.

by him as on the same horizon as those of Horncastle, Hamilton Hill, and the eastern portion of Wrawby-Bridge cutting *. He also states that the fossils of the cutting near Brigg are similar to those of Horncastle; but out of the nine species recorded from the former locality, five only occur at Horncastle. *Gryphæa dilatata* is by far the most common fossil in the Brigg cutting, but it has not been found in the clays at the other localities placed by Prof. Blake on this horizon. It will also be seen on the accompanying map † that the cutting east of Wrawby Bridge (2) lies east of the cutting

Fig. 2.—*Sketch Map of the Neighbourhood of Brigg.* (Scale ⅔ in. =1 mile.)



Railways.

- - - - - - Probable boundary between the Corallian and Kimeridge Clays.

1. Cutting east of Brigg.
2. Eastern portion of Wrawby-Bridge cutting.
3. Western portion of Wrawby-Bridge cutting.
4. Cutting N.W. of 3.

†. Worlaby Brickyard.

* *Op. cit.* p. 206. † Reduced from the 1″ ordnance map.

near Brigg (1), and since the line of strike of these clays appears to be approximately north and south, the clays in the first-named cutting must be on a higher horizon than those of the latter. The fossils obtained by myself from the Brigg cutting did not include a single Lower-Kimeridge species, but all occur in the selenitiferous clays further south, and the lithological character of the clays is identical, and they also lie on the same line of strike.

Prof. Blake's sketch map * is not quite correctly drawn in the neighbourhood of Brigg, Wrawby, and Barnetby Junction, and this gives an erroneous position to the sections in that district.

The *Upper Kimeridge Clays* of Lincolnshire have been described by Prof. Blake. They are well seen in the brickyard west of Fulletby, and are composed of thin papery shales in which *Discina latissima* occurs in some abundance. This was the only section visited in the clays of this horizon.

(b) *Correlation.*

It has already been shown that the zone of black selenitiferous clays overlies the Oxford Clays containing *cordati* Ammonites, *i. e.* the uppermost portion of that formation. They are not of Oxford-Clay age because:—

1. They do not contain a single species peculiar to the Oxford Clay.
2. The fossils are not pyritized;
3. Some of the fossils are characteristic of the Corallian.

The question now arises, are they of Corallian age? If these black clays are compared with the Ampthill Clay of Cambridgeshire it will be seen that they agree in the following particulars:—

1. Lithologically they are identical, both being dark clays often highly charged with selenite crystals;
2. The fossils *Ostrea deltoidea* and *Gryphæa dilatata* occur in both;
3. From the accompanying table it will be seen that out of 23 species determined, 16 are common to the Ampthill Clay of Cambridgeshire.

That these selenitiferous clays are Corallian is clearly shown by the following facts:—

1. They apparently overlie conformably the uppermost zone of Oxford Clay characterized by the presence of *cordati* Ammonites and *Amm. perarmatus.*
2. All the determined species which the writer has seen from these clays also occur in the Corallian of other areas, and, further, they contain several species which are peculiar to that formation, *e. g. Amm. cawtonensis*, *Pholadomya concentrica*, *Avicula pteropernoides*, &c.
3. The accompanying list of fossils does not include a single species peculiar to either the Oxford or Kimeridge Clays.

* *Op. cit.* p. 202.

List † of Fossils from the Black Selenitiferous Clays (Corallian) which overlie the Oxford Clay of Lincolnshire.

	Localities.							Geological Distribution.			
	Hawkstead Hall.	S.E. of Bardney.	South Kelsey.	North Kelsey.	Cutting East of Brigg.	Western portion of Wrawby-Bridge cutting.	Cutting west of Wrawby Bridge.	Oxford Clay and Older Beds.	Ampthill Clay.	Corallian.	Kimeridge Clay.
Ichthyosaurus, sp.	...	...	...	*							
Ammonites cordatus, *Sow.*	...	...	...	...	*	...	...	*	*	*	*
—— vertebralis, *Sow.*	...	M.P.G.	...	...	...	...	...	*	*	*	
—— excavatus, *Sow.*	*	...	...	...	...	...	...	*	*	*	
—— cawtonensis, *Bl. & H.*	...	M.P.G.	...	...	...	...	...	...	*	*	
—— plicatilis, *Sow.*	...	...	*	*	...	...	...	*	*	*	
—— achilles, *d'Orb.*	...	...	...	*	...	...	*	*	*	*	
—— decipiens, *Sow.*	...	...	*	...	...	...	...	...	...	*	*
Belemnites abbreviatus, *Mill.*	...	*	...	*	...	...	...	*	*	*	*
—— nitidus, *Dollf.*	...	*	...	...	...	...	...	*	*	*	*
Alaria bispinosa, *Phill.*	...	...	*	*	*	...	...	*	*	*	
Gryphæa dilatata, *Sow.*	...	*	*	...	*	...	...	*	*	*	
Ostrea deltoidea, *Sow.*	...	...	...	*	...	*	*	...	*	*	*
—— bullata, *Sow.*	...	...	*	...	...	...	...	...	...	*	
Pecten fibrosus, *Sow.*	...	...	*	...	...	...	...	*	*	*	
Pinna lanceolata, *Sow.*	...	...	...	*	...	...	...	...	...	*	*
Cardium striatulum, *Sow.*	...	...	...	*	...	...	...	*	...	...	*
Thracia depressa, *Sow.*	...	M.P.G.	...	*	...	...	...	*	*	*	*
Astarte supracorallina, *d'Orb.*	...	M.P.G.	...	*	...	...	...	...	*	*	*
Cucullæa contracta, *Phill.*	...	...	...	*	...	...	...	...	*	*	
Arca longipunctata, *Bl.*	...	M.P.G.	...	...	...	...	...	...	*	*	*
Pholadomya concentrica, *Röm.*	...	...	*	...	...	...	...	...	...	*	
Avicula pteropernoides, *Bl. & H.*	...	...	*	...	...	...	...	...	...	*	
Rhynchonella ‡, nov. sp.	...	...	*	...	*	*	...	...	...	...	...
Serpula tricarinata, *Sow*	...	...	...	...	*	...	...	*	...	*	
23 sp. determined.											
Total...	...	...	...	...	...	...	...	13	16	22	10

† The fossils included in this list are those which the writer collected himself or which were examined by him. Those marked M.P.G. are in the Museum of Practical Geology, Jermyn Street.

‡ These specimens were referred to J. F. Walker, Esq., who is of opinion that they are near to *R. subvariabilis*, of which they may be a variety, or they may be a new species.

4. *Gryphæa dilatata* and *Ostrea deltoidea* are found associated together in these selenitiferous clays, and also in the Corallian, but not in the Oxford or Kimeridge Clays. *Gryphæa dilatata* is recorded * from the Kimeridge Clay of Clophill, in Bedfordshire, and doubtfully from the same beds at Wolvercot, Bucks. Clophill is mapped as standing on Lower Greensand, and the clays which occur below it are probably Corallian. Ampthill, the typical locality for the Corallian clays, lies a little to the east of Clophill. *Ostrea deltoidea* is stated † to occur in the Oxford Clay of Wiltshire; but the writer is not aware of any other locality where this fossil occurs so low down in the series. With these two doubtful exceptions, the occurrence of *Gryphæa dilatata* ASSOCIATED WITH *Ostrea deltoidea* is strictly limited to the Corallian rocks, the former being found in the Lower Calcareous Grit and Coralline Oolite, and the latter in the Coralline Oolite and supra-Coralline Beds. In Lincolnshire *Gryphæa dilatata* is most common in the lower part of the selenitiferous clays, whilst *O. deltoidea* is more frequently met with in the upper part of these clays.

From these considerations, therefore, it seems highly probable that the black selenitiferous clays of Lincolnshire are partly represented by the Ampthill Clays further south, and that they are of Corallian age. Their fauna certainly links them more closely with the Corallian than with the Oxford or Kimeridge Clays. No limestone corresponding in age to the Elsworth rock, and separating the Oxford and Corallian Clays, has as yet been met with in Lincolnshire.

It should be mentioned that the occurrence of selenite crystals in these clays is of little classificatory value when taken alone, because such crystals are commonly met with in the Kimeridge Clay ‡, and to some extent in the Oxford Clay §.

The next zone of clay to be considered is that in which *Ostrea deltoidea* occurs in considerable abundance. Prof. Phillips, in describing the Kimeridge Clay near Oxford, states that near its base is a bed of *Ostrea deltoidea*, which has been recognized as far north as Yorkshire ‖. It has already been mentioned that at the base of the Kimeridge Clays of Cambridgeshire is a layer of phosphatic nodules. The clays immediately above are crowded with *Ostrea deltoidea*. Precisely the same thing occurs in Oxfordshire ¶. In Wiltshire *Ostrea deltoidea* is common in all the beds of the Kimeridge clay **.

* Fitton, Geol. Trans. 2nd ser. iv. p. 302.

† Ramsay, "Geol. of parts of Wilts and Gloucester" (Surv. Mem.), p. 20.

‡ "Geol. of Banbury" (Surv. Mem.), p. 46. "Geol. of Oxford and Berkshire" (Surv. Mem.), p. 9. Phillips's 'Geology of Oxford,' p. 325. Hudleston, "Yorkshire Oolites" (Proc. Geol. Assoc. vol. iv. p. 360), &c.

§ Quart. Journ. Geol. Soc. vol. xlii. p. 544.

‖ "Geol. of Oxford," p. 325.

¶ Quart. Journ. Geol. Soc. vol. xix. p. 236. Geol. Trans. 2nd ser. iv. p. 278.

** "Geology of parts of Wilts and Gloucester," p. 23.

On the south coast, Prof. Blake states * that the clays near the base of the Kimeridge Clay in Ringstead Bay are crowded with *Ostrea deltoidea*, and that west of Weymouth this same fossil is chiefly found near the base, but is not limited to this zone, as it occurs scattered through the clay. Waagen similarly mentions the occurrence of this fossil in the lower portion of the Kimeridge Clay at Ringstead Bay †.

It appears therefore that the basement-clays of the Lower Kimeridge throughout England are, in almost every locality where they have been observed, characterized by the abundance of *Ostrea deltoidea*. In Lincolnshire we find that at Woodhall Spa, West Barkwith, and apparently at North Kelsey, there are similar clays which should be placed on the same horizon. Prof. Judd is of opinion that the clays of Woodhall Spa belong to the lower portion of the Kimeridge Clay. He states that the Lower Kimeridge of Lincolnshire is divisible into two well-marked zones: in the upper, he adds, "*Ostrea deltoidea* never, I believe, occurs; while in the lower, which is well seen in a pit at Woodhall Spa, that fossil occurs in prodigious numbers" ‡. Prof. Blake also places these clays low down in the Kimeridge Clay.

Should these *deltoidea*-clays of Lincolnshire prove to be the basement beds of the Lower Kimeridge, and there is every reason for regarding them as such, there would be additional evidence for placing the underlying selenitiferous clays in the Corallian.

The clays of the succeeding zone have for their characteristic fossil *Ammonites alternans*, whilst this fossil is absent from the clays of the overlying zone.

In Cambridgeshire the following zones have been made out in the Lower Kimeridge :—

1. Clays with *Exogyra virgula*.
2. ,, *Ammonites alternans*.
3. ,, *Astarte supracorallina*.
4. ,, *Ostrea deltoidea*.

This arrangement differs somewhat from that of Lincolnshire. *Amm. alternans* is chiefly found in the upper portion of the Lower Kimeridge of Cambridgeshire, whereas in Lincolnshire it is characteristic of a lower zone. *Astarte supracorallina* occurs throughout the Lower Kimeridge of Lincolnshire; it has not as yet been observed in the upper zones in Cambridgeshire.

The fossil zones of the Kimeridge Clay are in some instances only of little value and are only applicable to a limited area. Prof. Blake states § that "in the Kimeridge Clay . . . . many fossils which in one locality are highly characteristic of a particular portion, are absent in that portion in another locality and characterize instead a lower or higher horizon." This statement fully bears out the observation mentioned above.

* *Op. cit.* p. 212.

† 'Versuch einer allg. Classif. der Schichten des oberen Jura,' p. 5.

‡ Quart. Journ. Geol. Soc. vol. xxiv. p. 240.

§ *Op. cit.* p. 197.

At Ringstead Bay Waagen mentions * the occurrence of *Ammonites alternans* in the clays which succeed those containing *Ostrea deltoidea*, whilst it is absent in his so-called Middle Kimeridge, which contains *Exogyra virgula*, and is what is generally considered as the upper portion of the Lower Kimeridge. In this area, therefore, the fossil zones of the Lower Kimeridge agree closely with those of Lincolnshire.

Exogyra virgula has not as yet been obtained from the Kimeridge Clays of Lincolnshire. In Cambridgeshire this fossil is found chiefly in the uppermost portion of the Lower Kimeridge, and is occasionally met with in the lower zones. *Exogyra virgula* should occur in Lincolnshire in clays a little higher in the series than those of Horncastle; but at present there appears to be no exposure between the Horncastle pits and the Upper Kimeridge of Fulletby.

The paucity of sections in the Upper Jurassic Clays of Lincolnshire renders the mapping of the various divisions rather unsatisfactory, and it must be remembered that the lines drawn on the accompanying map (fig. 1, p. 456), separating the various clays, have been set down in accordance with our present somewhat limited knowledge of their distribution. Subsequent discoveries may modify them considerably.

The boundaries of the Lower and Middle Jurassic and the Cretaceous have been taken in great measure from the Geological Survey Map (sheet 83).

4. Summary.

The facts stated in the foregoing paper indicate that the Upper Jurassic Clays of Lincolnshire may be divided into :—

3. *Kimeridge Clay* :—
    - (*b*) Upper Kimeridge : thin papery shales, with *Discina latissima*.
    - (*a*) Lower Kimeridge : dark clays, with septarian nodules, subdivided into :—
        - (iii.) Clays with *Amm. mutabilis*, *Astarte supracorallina*, &c.
        - (ii.) Clays with *Amm. alternans*.
        - (i.) Clays crowded with *Ostrea deltoidea*.
2. *Corallian*. Black selenitiferous clays, with *Amm. plicatilis*, *Amm. cawtonensis*, *Bel. abbreviatus*, *Gryphæa dilatata*, *Ostrea deltoidea*, &c.
1. *Oxford Clay*, subdivided into five palæontological zones, with the Kellaways Rock at its base.

Discussion.

Prof. Blake was fully prepared to hear of the separation of rocks of Corallian age in Lincolnshire, though as those rocks are themselves of an episodal character, the features which specially distinguish them are not likely to occur. Yet he was perfectly aware

* *Op. cit.* p. 5.

that the Ampthill Clay, for instance, contained spines of the Corallian Urchin *Cidaris florigemma*. But if from the Corallian rocks we eliminate the episodal fauna, we find that a change takes place in their midst, the lower portion being Oxfordian, the upper Kimeridgian; and hence if there be no fossils characteristic of the episode, there is little to distinguish the rocks of Corallian age beyond the mixture of the two faunas. In Yorkshire *Amm. excavatus* is found in the Kimeridge Clay. He did not consider the occurrence of selenite in the zone as of much value for purposes of correlation; it was a mere question of exposure and oxidation. He referred to places in the basal Kimeridge where *Ostrea deltoidea* is abundant, and expressed his agreement with Mr. Roberts.

Mr. Hudleston said that the thanks of geologists were especially due to Mr. Roberts for the care he had taken in making out the Upper Jurassic Clays of Fenland, a task which the nature of the country rendered both tiresome and difficult. This paper was a supplement to his valuable Sedgwick Prize Essay, and enabled us to trace the Corallian Clays of Cambridgeshire still further. But in what is now the county of Lincoln the pelolithic conditions of the period attained their maximum, and there are neither limestones nor grits to help in defining the horizon. Hence the resemblance to typical Corallians would naturally be feebler as we proceeded northwards from Cambridgeshire.

Notwithstanding the development of typical Corallian rocks round the Vale of Pickering, it was found, on making the Hull and Barnsley railway, that the whole of this series of grits and limestones had disappeared a few miles south of the Pocklington axis. Hence, although the fauna of the Corallian clays of Lincolnshire reminded him to a certain extent of the North-Grimston Cement-stone, the affinities of the Lincolnshire beds were rather with those of Cambridgeshire. Referring to Mr. Roberts's map, he thought that possibly the Survey might shrink from the additional task of defining the limits of a third clay.

The Author, in reply to Prof. Blake, said that the selenitiferous clays contained several characteristic Corallian fossils. The lower part of this zone was allied to the Oxford Clay, and its upper part to the Kimeridge Clay. He thought there must be some peculiarity in the lithological character of those clays which contained so much selenite.

35. *On some* Bryozoa *from the* Inferior Oolite *of* Shipton Gorge, Dorset. By Edwin A. Walford, Esq., F.G.S.—Part I. (Read April 3, 1889.)

[Plates XVII.-XIX.]

So little attention appears to have been paid by British palæontologists to the Jurassic Bryozoa, that a few scattered papers constitute the literature of the subject, and hardly a dozen new forms have been described since the appearance of Haime's Monograph in 1854. In a paper on some Lias Polyzoa *, I believe I have given the titles of nearly all of the papers. Mr. Vine's Richmond report † and two later contributions complete the list. This neglect can scarcely be accounted for by the absence of material to work upon, for though the argillaceous seas of the Lias were not favourable to the development of the Bryozoa, either in numbers or species, yet under the calcareous conditions of the Inferior and Great Oolite the contrary was the case. The reason may be sought for, perhaps, in the frequently unsatisfactory state of preservation of the delicate features necessary for their study, as well as in the difficulties into which the classification has drifted. Certain it is that too many species have been created out of ill-preserved examples, and thus another barrier has been raised in the way of systematic nomenclature. It can scarcely, however, be said that there is yet formed a natural system of classification for the division to which most of the Lower Jurassic forms belong.

In 1885, when studying the Inferior Oolite in the neighbourhood of Bridport, I detected in a small quarry some marly beds rich in numerous species of Bryozoa, and containing an otherwise remarkable fauna—Echinoderms, small Brachiopods (*Crania*, *Thecidea*, &c.), Sponges, and Foraminifera. The tranquil conditions prevailing during the deposition of the beds are indicated by the presence of so many slender and arborescent forms of Bryozoa, as well as by the Crinoids and Sponges. That the horizon of the Inferior Oolite in which the forms mentioned are found is the upper division is shown by the presence of a few characteristic shells, notably *Terebratula Phillipsii*, *Crania canalis*, Moore, and *Acanthothyris panacanthina*, Buckm. & Walker. The zone is apparently that of *Ammonites Parkinsoni*. It is worth note that Eug. Deslongchamps ‡ quotes a somewhat similar fauna of Echinoderms, Bryozoa, and Sponges as occurring in the "Oolithe Blanche" of Calvados.

The following section will illustrate the position of the calcareo-

* "On some Polyzoa from the Lias," by E. A. Walford, F.G.S., Quart. Journ. Geol. Soc. vol. xliii. (1887), p. 632.

† "On Polyzoa found in the boring at Richmond, Surrey," by G. R. Vine, Quart. Journ. Geol. Soc. vol. xl. (1884), p. 784.

‡ Etudes Jurass. Inf. de la Normandie, par M. Eug. Eudes Deslongchamps, p. 109 (Paris & Caen, 1864).

argillaceous beds from which the series of fossils has been collected:—

Quarry (Inferior Oolite) near New Inn, Shipton Gorge.

	ft.	in.
1. Humus	1	2
2. Compact grey limestone, weathering brown, broken and rubbly	1	9
3. Grey and brown marls, with fragments of limestone, Bryozoa, Sponges, &c.	0	4
4. Broken limestone, rather argillaceous	0	6
5. Grey and brown marly clay, with Bryozoa, Sponges, &c.	1	2
6. Compact grey limestone, somewhat marly and oolitic. Base not shown	3	0

From this one locality I am able to recognize about fifty different forms representing twelve or more genera, the number being nearly equal to the whole of those described by Haime from the Lias to the Kimeridge Clay.

At the outset one has to consider the question as to how far it is possible, or rather practicable, to travel in the recognition of cell-form and disregard of zoarial growth. Certainly, to put the latter wholly aside would, in the present state of classification, lead to utter confusion, and hence, for a time, the present system must be adhered to. Nevertheless, it will be necessary to acknowledge the great variability of zoarial form, a fact which Prof. Smitt's series of papers * has demonstrated beyond a doubt. To some extent it will be my endeavour to follow, in the examination of this series of fossil Bryozoa, the laws of evolution he has so well traced.

Successive writers have suggested divisions for the Cyclostomata, which each author in turn has modified or altered, but amongst them the simple divisions of Mr. Waters †, based upon the Hincksian system, seem most feasible. He proposes "that we should divide the Cyclostomata into two subdivisions, namely, first the *Parallelata*, or those in which the surface of the zoarium is to a considerable extent formed of the lateral walls of the zoœcia, of which *Crisia*, *Entalophora*, *Diastopora*, and *Tubulipora* may be taken as types; and, secondly, the *Rectangulata*, or those in which the zoœcia or cancelli open for the most part at right angles to the axis or surface of the zoarium or subcolony, of which *Heteropora*, *Lichenopora*, &c. may be taken as typical." Still later, Marsson in his beautifully illustrated memoir on the Bryozoa of the Rügen Chalk ‡, re-arranges the Cyclostomata, leaning largely upon the character of the subsidiary cells, the importance of which he thinks has been overlooked. Students of the Hincksian system will look, however, with dismay at a classification which groups under one family *Heteropora* and *Spiropora*, whilst it widely separates *Defrancia* and *Diastopora*.

* "Kritisk Forteckn. öfv. Skand. Hafs-Bryozoer," af F. A. Smitt, Öfvers. af K. Vet.-Akad. Förh. 1864–8 & 1871.

† "On Tertiary Cyclost. Bryozoa from New Zealand," by A. W. Waters, Quart. Journ. Geol. Soc. vol. xliii. (1887), p. 337.

‡ "Die Bryozoen der weiss. Schreibkr. der Insel Rügen," Päl. Abh. Dames u. Kayser, Band iv. Heft i. (Berlin, 1887).

Pergens and Meunier, in their description of the Faxoe Bryozoa *, point out the deficiencies in d'Orbigny's system, and add that in their opinion the time for a new classification has not yet arrived. They base their work upon the Smitt-Hincksian system, without, however, as they state, acknowledging the pretended constancy of the zoœcial orifice, which presents remarkable differences in many of the species. We must acknowledge the keenness of their criticism when they go on to say that to substitute one classification based principally upon a single character, that of the mouth of a cell, for that which has in view the form of a colony, is to replace one artificial classification by another almost further removed from the reality, and leads to ignoring what are really the staple characters in one division when applied to the other.

Suborder CYCLOSTOMATA.

Division **Parallelata.**

Family TUBULIPORIDÆ.

Genus STOMATOPORA.

Stomatopora, Bronn, Pflanzenth. p. 27 (1825).

1. STOMATOPORA DICHOTOMA, Lamx.

Alecto dichotoma, Lamouroux, Exp. méth. des genres des Pol. p. 84, pl. 81. figs. 12, 13, 14 (1821).

Aulopora dichotoma, Goldfuss, Petref. Germ. t. i. p. 218, pl. 65. fig. 2 (1833).

Alecto dichotoma, Morris, Catalogue of Brit. Fossils, p. 30 (1843); Michelin, Icon. Zoophyt. p. 238 (1846), *non* pl. 2. fig. 10, p. 10.

Stomatopora dichotoma, Haime, Descr. des Bryozoaires Foss. de la Form. Jurass. p. 160, pl. 6. fig. 1, Mém. Soc. Géol. de France, 1854; Reuss, Bryozoen, Anthoz. u. Spong. d. braun. Jura v. Balin bei Krakau, p. 2, pl. 1. fig. 4, Abhandl. Akad. d. Wissensch. Wien, mathem.-naturw. Cl. xxvii. Bd. (1867); Brauns, Die Bryozoen des mittl. Jura der Gegend v. Metz, p. 320, Zeitschr. d. deutsch. geolog. Gesellschaft, Jahrg. 1879; Vine, Polyzoa found in the Boring at Richmond, Surrey, p. 786, fig. 1, Quart. Journ. Geol. Soc. vol. xl. (1884); Vine, Notes on the Polyzoa of Caen and Ranville, p. 12, Journ. Northampton. Nat. Hist. Soc. & Field Club (1888).

Zoœcial length 0·6 millim., width 0·3; aperture 0·07.

I find two slightly diverging forms—the typical one with measurements as quoted, and agreeing well with Haime's figures †; the other, as figured by Reuss ‡, with rather shorter and more puffed-

* "Bryoz. Garumn. de Faxe," Ann. de la Soc. Malacolog. de Belg. t. xxi.

† "Descr. des Bryozoaires Foss." par Jules Haime, Mém. Soc. Géol. de France, 2e série, t. v. pl. 1. fig. 1 (1854).

‡ "Bryozoen, Anthoz. u. Spong. d. braun. Jura v. Balin bei Krakau," Abh. Akad. d. Wissensch. Wien, mathem.-naturw. Cl. xxvii. Bd. 1867, Taf. 1. fig. 3 *b*.

out zoœcia (length 0·5 millim., width 0·4), with greater dilatation at the base. Haime describes the species as varying in different localities from $\frac{1}{3}$ to $\frac{1}{2}$ millim. in the width of the zoœcia, and the length of the zoœcia he cites as generally three or four times the diameter of the peristome. The Dorsetshire forms from the Inferior Oolite are slightly longer than Haime's from the Great Oolite. Occasionally one or more cells will become dilated and inflated at the proximal end, presenting quite a different zoœcial type. The Ranville specimens from the Forest Marble are of Reuss's type; and the figures in 'Petrefacta Germaniæ,' pl. lxv., indicate two kinds of cells. Smitt * places *St. dichotoma*, M.-Edw. (?), under his β, forma *serpens* of *Tubulipora incrassata,* d'Orb.

2. Stomatopora spirata, sp. nov. (Pl. XVIII. figs. 6 *a, b.*)

Zoœcial length 0·2 to 0·3 millim., width 0·2 to 0·26; aperture 0·06.

Zoarium adnate, with uniserial zoœcia disposed in a semicircular or spiral series of from ten to twenty without bifurcation. Zoœcia short, only one third longer than wide, cylindrical, slightly decreasing in size from base to mouth, free for about one third of their length. Basal part of zoœcia elevated, and without widened margins. The exsert part narrows but very little towards the aperture. Aperture oval. Surface punctulate. Ovicells (?).

The species is well distinguished by the short cylindrical zoœcia with slightly elevated bases and regular arrangement. Rare.

3. Stomatopora dichotomoides, d'Orb.

Stomatopora dichotomoides, d'Orbigny, Paléont. Franç., Terr. Crét. t. v. p. 834 (1850–52); Haime, Descr. des Bryozoaires Foss. de la Form. Jurass. p. 163, pl. 6. fig. 2, Mém. Soc. Géol. de France, 1854; Brauns, Die Bryozoen der mittl. Jura der Gegend v. Metz, p. 322 (1879); Reuss, Bryozoen, Anthoz. u. Spong. d. braun. Jura, p. 3 (1867); Vine, On Polyzoa of Caen and Ranville, p. 12 (1888).

Zoœcial length 0·6 millim., width 0·17 to 0·1; aperture 0·06.

The elongated slender zoœcia of subconical form seem to fairly distinguish the species.

Haime † figures the zoœcia widening from distal to proximal extremity; one meets, however, with a varying form in which the cells are leathern-bottle-shaped.

Var. attenuata. (Pl. XVIII. fig. 9.)

Zoœcial length 0·6 millim., width 0·2; aperture 0·07.

Zoarium uniserial, but with zoœcia of nearly uniform thickness, excepting the slightly tapering free part, which rises almost vertically, and is $\frac{1}{3}$ the length of the whole cell. The adherent part of the zoarium is scarcely dilated. I can detect two kinds of surface-

* "Krit. fort. öfver Skand. Hafs-Bryozoer," af F. A. Smitt, Öfvers. af K. Vet.-Akad. Förh. 1866, p. 402.

† "Descr. des Bryozoaires Foss." par Jules Haime, Mém. Soc. Géol. de France, 2e série, t. v. pl. 1. fig. 1 (1854).

pores: the larger are few in number, tubular and slightly exsert; the smaller are exceedingly fine, and cover the whole surface. Aperture oval.

It will be seen, by reference to the figure, that the zoœcia have scarcely any of the claviform character of Haime's type. The preservation of the delicate terminations is due to the protection given by a colony of large *Proboscinæ*, which occupy the interior of the same Aviculoid shell.

4. Stomatopora porrecta, sp. nov. (Pl. XVIII. figs. 7 *a*, *b*, 8.)

Zoœcial length 1 to 1·6 millim., width 0·23; aperture 0·1.

Zoarium dichotomously branched, with uniserial, very lengthened, and sinuous (*Serpula*-like) zoœcia. Zoœcia rather irregularly cylindrical, coarsely wrinkled, and punctate. The exsert part of the cell is but slightly raised, and is ordinarily about $\frac{1}{5}$ of the whole in length; the terminations, however, do not seem to be perfect. Aperture oval. Ovicell (?). If the shield-like body (Pl. XVIII. fig. 8), from beneath which the branches emerge, should be the ovicell of the species, it will be of a different type from the surface-inflations of the zoarium common in the genus. The tubular surface-pores on it are the same as on the cylindrical zoœcia.

The long *Serpula*-like zoœcia with coarse transverse wrinkles are fairly distinctive. It is open to question whether the fragment of a Lias fossil, figured on plate xxv. fig. 10, vol. xliii. Quart. Journ. Geol. Soc., is referable to the same species, as I at one time supposed it to be: there the free part of the cell is much longer. The "Calcaire à Polypiers" at Ranville, Calvados, yields a similar form to *S. porrecta*.

5. Stomatopora, sp.

Zoarial length 0·4 to 0·5 millim., width 0·3; aperture 0·1.

Zoarium adnate, composed of a linear series of ten inflated and conical zoœcia without dilatation at the base. Zoœcia transversely wrinkled and coarsely punctate. Aperture oval.

There are one or two perforations in each cell about 0·3 millim. in diameter at irregular distances below the peristomes, recalling the features of certain Chilostomatous cells. The example, however, is a solitary one and ill-preserved. *Stomatopora granulata*, M.-Edw., is nearly related to it.

Proboscina.

Proboscina (pars), Audouin in Savigny, Descr. de l'Egypte, p. 236 (1826).

Proboscina, d'Orbigny, Paléont. Franç., Terr. Crét. t. v. p. 884 (1854).

So slight are the distinctions between the genera *Stomatopora* and *Proboscina* that it has been more as a matter of convenience in this individual instance that I have placed the uniserial forms under the head of the former, than from any sense of there being a natural line

of demarcation between the two genera. The series to be subsequently dealt with furnish a good illustration of the wide variation in mode of growth of one zoœcial type, and it has only been by the collection of a large number of examples that the connecting-links have been found. Forms of considerable difference in size of cell and aperture are seen to go through similar phases of zoarial growth, so that one cannot do otherwise than recognize their close relationship. Just as Prof. Smitt has shown *Tubulipora incrassata*, d'Orb., to pass through the stages of *Stomatopora* and *Proboscina* to that of *Tubulipora*, so I shall endeavour to demonstrate the stages of growth of one type from *Stomatopora* to *Proboscina*, and thence to *Tubulipora* or *Diastopora*. Hincks has also pointed out how shadowy are the distinctions between these genera. At present, however, no more satisfactory method of classification seems to be practicable than the one now in use; hence the forms will be placed under the old family names, but with a uniform specific name.

The group for illustration is figured on Pl. XVII. figs. 1, 2, 3, 7, 8, and Pl. XVIII. figs. 10, 11, 12. Its earliest stage is that of a *Stomatopora* with uniserial zoœcia and widely dilated margin (Pl. XVII. fig. 1), merging into an irregular bi- or triserial growth (Pl. XVII. figs. 2, 3). The anastomosing of the branches is frequently so dense as to produce a *Diastopora*-like colony (Pl. XVII. fig. 8), and all intermediate phases of growth are met with. Such colonies are frequently recognizable by the trailing lines of the branches (Pl. XVII. fig. 7), but forms occur (Pl. XVII. fig. 8) which are not distinguishable from *Diastoporæ* of the ordinary discoid growth. When the zoœcia are thus massed there is a tendency to the production of erect branches, as shown in the capitulum on the colony (Pl. XVII. fig. 7), and though it is not at present clear, there is reason to suppose that the form subsequently described as *Entalophora magnipora* (Pl. XIX. figs. 11, 12) may be the erect stage. The interweaving of the Stomatoporoid branches gives rise to another phase of growth (Pl. XVIII. figs. 10, 11, 12), Tubuliporoid, and it will be seen that the ventricose forms approach *T. ventricosa*, Busk. Considerable variability is also met with in the shape of the zoœcia: some are cylindrical throughout, whilst others have the exsert parts conical, or, again, they may be leathern-bottle-shaped (utriform). The dimensions of the zoœcia in width vary from 0·3 millim. to 0·5 millim., the apertures from 0·13 millim. to 0·2 millim.

1. Proboscina spatiosa, sp. nov. (Pl. XVII. figs. 1–3.)

Zoœcial length 1·16 to 0·5 millim., width 0·5 to 0·7; aperture 0·13 to 0·2.

Zoarium adnate, ramose, varying from a uniserial to an irregular bi-, tri-, or multiserial arrangement of zoœcia, the branches frequently anastomosing. Zoœcia ranging from nearly immersed to partially free, of variable shape, cylindrical or somewhat compressed, the free part conical or of uniform diameter, though more rarely the whole cell is leathern-bottle-shaped. The zoœcia have, especially in the uniserial stage, widely dilated bases. Aperture orbicular or

elliptical, with closures well within the orifice and punctate like the surface of the zoarium. Zoarial surface coarsely wrinkled and punctate, the terminations of the pores protruding slightly above the surface. The cluster of cells connected with the colony shown (Pl. XVII. fig. 3) indicates a mode of gemmation similar to that Hincks has described in *Stomatopora fasciculata* (Brit. Marine Polyzoa, p. 441).

From *S. repens* (Busk), Crag Polyzoa, pl. xx. fig. 5, it is separated by the larger cells and more irregular habit; from *S. major*, Johnst., also by the latter feature and by the shape of the zoœcia.

Var. BREVIS, nov. (Pl. XVIII. figs. 1, 2.)

Zoœcial length 0·93 to 0·6 millim., width 0·2–0·3; aperture 0·13–0·17.

Zoarium of similar habit to that of *S. spatiosa*, but with rather smaller and less robust zoœcia, their exsert parts longer and only slightly diminishing in size towards the aperture. In both uniserial and other stages it is frequently met with encircling the stems of *Entalophora*. Ovicell (?) apparently an inflation of a single cell.

Var. BREVIOR, nov. (Pl. XVIII. figs. 3–5.)

Zoœcial length 0·7 millim., width 0·3; aperture 0·1.

The distinction from var. *brevis* is almost wholly in point of size of zoœcia, which are generally shorter in proportion to the width and with smaller apertures. A cluster of small cells occurs in one specimen, of similar type to that noticed above.

2. PROBOSCINA INCRUSTANS, sp. nov. (Pl. XVII. figs. 4–6.)

Zoœcial length 0·6 millim., width 0·17; aperture 0·1.

Zoarium adnate, ramose, passing almost immediately from the one or two primary cells into a crowded irregular arrangement of zoœcia (fig. 4). Zoœcia cylindrical, compressed (Pl. XVII. fig. 6, *a*, *b*), free for about one third of their length, and less robust than in *P. spatiosa*, var. *brevior*. Aperture elliptical or rarely orbicular. Surface punctate and transversely wrinkled. Ovicells pyramidal swellings of the zoarium, rising above and enveloping one or more zoœcia and opening at the summit. The specimen figured is attached to an *Echinus*-spine, and occasionally the species is found enveloping stems of *Entalophora*.

It differs from *Proboscina Jacquoti* and *P. Alfredi*, Haime, by the smaller size and the shape of the zoœcia and their apertures, also by the closer arrangement of the zoœcia and the peculiar form of ovicell (fig. 6, *c*).

TUBULIPORA.

Tubulipora, Lamarck, Système d. Animaux sans Vertèbres, 1816.

1. TUBULIPORA SPATIOSA, sp. nov. (Pl. XVIII. figs. 10, 11.)

Zoœcial width 0·4 millim.; aperture 0·16 to 0·17.

Zoarium erect or suberect, pyriform or cylindrical. The colony

commences with a Stomatoporoid form of growth, and spreads out rapidly, the branches frequently coalescing. Zoœcia cylindrical, the exsert parts either of uniform diameter or tapering towards the aperture, or slightly flattened. Aperture orbicular or elliptical, the cell-walls thick. In well-preserved examples the mouth is lipped similarly to the species *Tubulipora ventricosa*, Busk. Closures well within the mouth, punctate. Ovicell a globose swelling, somewhat pyramidal, involving one or more zoœcia. Zoarial surface coarsely wrinkled and punctate.

The form (Pl. XVIII. fig. 11) tends to a *Pustulopora*-like growth, and one sees the funnel-shaped ovicell of a similar type to that found on *Entalophora magnipora* (Pl. XIX. fig. 11). Other but suberect forms approach *Tubulipora flabellaris*, Johnst.

There is little doubt of this species being another stage of growth of my *Proboscina spatiosa*. It has many points of resemblance to *Tubulipora ventricosa*, Busk, but yet I think it merits distinction.

Just as I noted of *Proboscina spatiosa*, that it was connected with forms of identical zoarial habit, varying principally in size of zoœcia, so also in this group are specimens with zoœcia less robust, measuring but 0·3 millim. in width, and with apertures of only 0·13 millim. in diameter.

Idmonea.

Idmonea, Lamouroux, Exp. méth. des genres des Pol. p. 80 (1821).

1. Idmonea stomatoporoides, sp. nov. (Pl. XIX. figs. 5, 6.)

Zoarial length 4·0 millim.; width 0·5; aperture (perfect) 0·03, (worn) 0·07.

Zoarium wholly adnate, broadly angular, straight, waved or encircling, attached to stems of *Entalophora* or shells. Zoœcia nearly immersed, arranged in pairs obliquely, so as to give the appearance of alternating apertures on right and left sides of zoarial ridge, often single and irregular at the beginning of a colony. Proximal extremities of zoœcia erect and mammiform. Aperture orbicular.

The size of the specimens shows this species not to be an immature stage of *I. triquetra*, Lamx., which, moreover, has six matured cells on each side of the zoarium when adherent.

2. Idmonea triquetra, Lamx., var. Y-formis, nov. (Pl. XIX. figs. 3, 4.)

Idmonea triquetra, Lamouroux, Exp. méth. des genres des Pol. p. 80, pl. 79. figs. 13–15 (1821); Morris, Catalogue of Brit. Foss. p. 40 (1843); d'Orbigny, Paléont. Franç., Terr. Crét. t. v. pp. 729, 751 (1850–52); Haime, Descr. des Bryoz. Foss. de la Form. Jurass. p. 171, pl. 7. fig. 1 (1854); Vine, Polyzoa found in Richmond Boring, p. 790, Q. J. G. S. 1884; Sorby and Vine, Fifth Rep. on Fossil Polyzoa, Brit. Assoc. p. 43 (1884); Vine, Notes on Polyzoa of Caen and Ranville, p. 7, Journ. Northampton. Nat. Hist. Soc. 1888.

Length of zoarium 4·7 millim., width at base 0·7; zoœcial width 0·27; aperture 0·1.

Zoarium Y-shaped, erect, with roughly triangular stem and branches. Zoœcia in irregular transverse rows or clusters, 3 or 4 on each of the two front angles of the zoarium. The front pair form a kind of mesial ridge, are mammiform, larger, and have larger apertures, which are placed obliquely so as to appear alternating. Outermost zoœcia pentagonal with small apertures, the two next are less distinctly pentagonal. The ornamental areolation of the dorsal surface is given by the pentagonal walls of the blind cells. Aperture orbicular, with a calcareous centrally perforate closure within the mouth. Surface punctate. Ovicells pyriform inflations involving two or more zoœcial tubes, or pyriform sacs disposed on the front of the branches.

Though the specimens are all Y-shaped, there is evidence of other branches being thrown out. It may be regarded as an erect variety of *Idmonea triquetra*, Lamx., differing also in having fewer developed cells in each row.

Another diverging form commences growth with four cells placed transversely but opening at irregular intervals. The developed zoœcia subsequently increase to six, with the middle pair but very little elevated above those on the sides. Surface, aperture, and closure the same as in the type.

IDMONEA TRIQUETRA, Lamx., var. PARKINSONI, nov. (Pl. XVIII. fig. 13.)

Lateral width of zoarium 0·9 millim., thickness 0·6; mesial apertures 0·1.

Zoarium erect, ovately triangular, and slightly claviform. Base of stem at point of attachment narrow, rapidly increasing to normal width, and becoming somewhat sinuous in its course of growth. Zoœcia in the poriferous area, three on each side, rarely four, arranged in transverse rows, with thick walls rising above the zoœcial surface. The two front zoœcia are larger, mammiform, and divergent. Non-poriferous area rounded, ornamented with the hexagonal or pentagonal walls of the blind cells. Apertures oval. Surface punctulate with terminal papillæ. Ovicells irregular globose swellings enveloping two or three zoœcia, and placed ordinarily in front of the zoarium.

3. IDMONEA CLAVIFORMIS, sp. nov. (Pl. XIX. figs. 1, 2.)

Zoarial length 5·0 millim., zoarial lateral width 1·3; apertures, perfect 0·03, worn 0·1.

Zoarium erect, clavate, ovately triangular with flattened sides, ordinarily curving backwards from above the middle. Zoœcia in curved alternate rows, five or six peristomes in each row on the poriferous sides of the zoarium, the median pair teat-like and forming a pseudo-carina. The width of the non-poriferous dorsal area is two thirds only of the breadth of the sides. Ovicells irregular

leech-like swellings between or enveloping six or eight of the front cells, punctulate, the pores finer than on the zoarial surface. There are calcareous floors or closures with a central perforation at about the point where the free part of the cell commences.

A semi-adherent form varies but little in zoœcial arrangement, but has a sharply triangular outline where attached. One fragment only of a numerous series of *Idmoneæ* from Ranville in my collection has an approximate clavate form.

An abnormal form of this species (Pl. XIX. fig. 2) shows the mesial zoœcia much more produced and becoming prominently conical towards the aperture. The zoarium is more globosely claviform, and has new colonies or branches starting from the non-poriferous area.

The whole of the *Idmonea-triquetra* series from the Inferior Oolite of Dorsetshire, when compared with the allied forms from the Forest Marble ("Calcaire à Polypiers") of Ranville, show a greater degree of robustness. The similarity of the variations of growth on each horizon impresses upon the observer belief in their belonging to one type The typical *I. triquetra*, Lamx., is adherent and broadly triangular, with numerous rows of apertures on each of the upper sides. In the Dorsetshire series a modified form of the type occurs. In the several Dorset varieties the exsert parts of the zoœcia are more prominent, especially the mesial ones, which are mammiform, and the ridge-like front more protuberant than in the Ranville form.

Bisidmonea.

Bisidmonea, d'Orbigny, Paléont. Franç., Terr. Crét. t. v. p. 720 (1852).

D'Orbigny characterizes this genus as having quadrangular stems and branches, with alternating lines of cells upon the face of each of the four angles. Apertures prominent, placed one above the other in transverse lines. He adds that it resembles a double *Idmonea*. One finds, however, that the quadrangular stems merge into ovals with less interrupted lines of zoœcia, and on this ground as well as its mode of reproduction the species is removed from *Entalophora*.

Vine, in his remarks upon *E. tetragona* *, says:—"I am not surprised that d'Orbigny should suggest a new generic term, *Bisidmonea*, for this species, as in some of the finer branches the name appears to me to be eminently suitable." Waters, when describing *Idmonea bifrons* †, in which the annulations of zoœcia are interrupted by two mesial lines, speaks of it as looking like a connecting-link between the *Spiropora* form of *Entalophora* and typical *Idmoneæ*.

* Vine, G. R., "Notes on the Polyzoa of Caen and Ranville &c.," Journ. Northampton. Nat. Hist. Soc. vol. v. p. 10 (1888).

† Waters, A. W., "On Fossil Cyclostomatous Bryozoa from Australia," Quart. Journ. Geol. Soc. vol. xl. p. 685.

1. Bisidmonea tetragona (Lamx.), var. ovalis, nov. (Pl. XIX. figs. 7–9.)

Spiropora tetragona, Lamouroux, Exp. Méth. des genres des Pol. p. 85, pl. 82. figs. 9 & 10 (1821).

Cricopora tetragona, Michelin, Icon. Zooph. p. 235, pl. 55. fig. 12 (1845).

Entalophora tetragona, d'Orbigny, Pal. Franç., Terr. Crét. p. 779 (1850–52).

Spiropora tetragona, Haime, Descr. des Bryoz. Foss. Jurass. p. 197 (1854).

Entalophora tetragona, Vine, Notes on Polyzoa of Caen and Ranville, p. 90 (1888).

Zoarial width 1·4 millim.; zoarial width short axis 1·0; zoœcial width 0·2; apertures 0·13 to 0·8.

Zoarium erect, ramose; stem and branches cylindrical and compressed. Zoœcia short (0·3 millim. in length), ovoid, arranged in irregularly oblique annulations, walls thick and projecting above the zoœcial surface. The zoœcia forming the ridge of the oval stem are large as in *Idmonea*. Apertures elliptical, rarely orbicular, with centrally perforate and punctulate closures within the orifice. Zoarial surface punctate. Ovicells long, punctulate, leech-like swellings along the ridge of the oval stem, between or enveloping ten or twelve of the large zoœcia.

Vine * prefers to retain Lamouroux's generic name *Entalophora* for the Ranville species; but if mode of reproduction, which is exactly similar in some varieties of *Idmonea* I have described, is of generic value when combined with a distinct shape of cell and aperture, then d'Orbigny's genus provides a good resting-place for such transition forms between *Idmonea* and *Entalophora*.

Spiropora compressa, Haime, appears to be nearly related.

Entalophora.

Entalophora, Lamouroux, Exp. Méth. des Genres des Pol. p. 81 (1821).

1. Entalophora richmondiense, Vine, var.

Entalophora richmondiensis, Vine, Polyzoa found in Boring at Richmond, p. 791, fig. 3, Quart. Journ. Geol. Soc. vol. xl. 1884.

Zoœcial length 0·3 to 0·5 millim., width 0·2; aperture 0·07 to 0·1.

The size of zoarium, zoœcia, and apertures agrees fairly with Vine's Richmond species. The zoœcia, however, vary in size of apertures, which are frequently furnished with closures. The arrangement of the zoœcia differs in that the mouths open one above the other in each annulation, whereas in *E. richmondiense*, accord-

* "Notes on the Polyzoa of Caen and Ranville," by G. R. Vine, Journ. Northampt. Nat. Hist. Soc. vol. v. p. 10 (1888).

ing to Vine, the apertures of one row of annulations are on a line with the cell-walls of the succeeding row.

The same difference may be noted between the several species of *Entalophora* and *Spiropora* from Ranville, which Haime figures. The zoœcia are ordinarily disposed in alternating rows, whereas in the Dorset forms the cell-walls are thicker and the cell arrangement in longitudinal lines.

2. Entalophora magnipora, sp. nov. (Pl. XIX. figs. 11, 12.)

Width of zoarium 1·8 millim.; zoœcial length 0·9 to 1, width 0·3; aperture 0·13.

Zoarium erect, ramose and robust, the stem nearly 2 millim. thick, dichotomously branched. Zoœcia large, the peristomes arranged at a spiral angle of from 40° to 50°. Zoœcia free for about one fourth of their length; the exsert part, where perfect, diminishing in size towards the aperture, where it becomes more conical, and frequently projecting horizontally from the stem. Apertures orbicular, ten to each annulation, closures within the orifice. Surface of zoarium punctate and wrinkled. Surface-pores slightly exsert. Ovicells funnel-shaped inflations enveloping one or more cells (Pl. XIX. fig. 11).

A longitudinal section shows large communication-pores in the cell-walls of the interior of the zoarium; and I think there is evidence of club-like rays on the surface of the inner wall as described by Waters in some Australian *Entalophoræ* *. Between the surface-pores also there are traces of fine granulation. The zoœcial tubes in section are seen to contain coloured grains probably of oxide of iron.

As I have before noted, this may be the erect stage of *Proboscina spatiosa*, but from other *Entalophoræ* it is marked off by the greater thickness of the zoarium, and by the large zoœcia and apertures. It has, however, some relationship to *Entalophora raripora*, d'Orb.

3. Entalophora raripora, d'Orb. (Pl. XIX. fig. 10.)

Entalophora raripora, d'Orb. Prodr. de Paléont. Strat. ii. p. 267 (1850).

Entalophora santonensis, d'Orb. Pal. Franç., Terr. Crét. pl. 623. figs. 15–17 (1850–52).

Entalophora raripora, d'Orb. Pal. Franç., Terr. Crét. p. 787, pl. 621. figs. 1–3 (1850–52); Novak, Beitr. z. Kenntn. d. Byroz. d. Böhm. Kreide, p. 32, pl. 8. fig. 2, pl. 10. figs. 1 & 2 (Wien, 1877); Waters, Foss. Cyclost. Bryoz. from Australia, Quart. Journ. Geol. Soc. vol. xl. p. 686 (1884).

Zoarial width 1·2 to 0·8 millim.; zoœcial length 1·3, width 0·4; aperture 0·13 to 0·17.

Some of the specimens are rather more robust than those figured

* "On Tertiary Cyclostomatous Bryozoa from New Zealand," by A. W. Waters, F.G.S., Quart. Journ. Geol. Soc. 1887, p. 340.

by d'Orbigny. The section (Pl. XIX. fig. 10) illustrates the internal arrangement of the zoœcia and shows the large surface-pores. Longitudinal sections exhibit the cells containing coloured grains probably of oxide of iron.

4. Entalophora raripora, d'Orb., var. anomala, Reuss.

Entalophora anomala, Manzoni, Brioz. foss. d. Miocene d'Austr. ed Ungh. p. 10, pl. 9. fig. 3 (Denkschr. Akad. Wiss. Wien, Bd. xxxix. 1878).

Zoarial width 1·2 to 0·9 millim.; zoœcial length 1·6, width 0·3; aperture 0·17.

The zoœcia are longer and rather less wide than in d'Orbigny's type and open in fours around the stem. Waters, however, classes *E. anomala*, Reuss, as synonymous with *E. raripora*, d'Orb. *E. gracilis*, d'Orb., would be as well, I think, classed as a variety of *E. raripora* also, so then my variety *corrugata* as well as *anomala*, Reuss, might be placed under the head *E. raripora*, d'Orb. One finds numerous intermediate forms.

5. Entalophora subgracilis, d'Orb., var. corrugata, nov. (Pl. XVIII. fig. 14.)

Entalophora subgracilis, d'Orb. Prodr. ii. p. 267 (1847); Paléont. Franç., Terr. Crét. p. 788, pl. 621. figs. 4–6 (1850–52).

Zoarial width 0·5 millim.; zoœcial length 1·3, width 0·2; aperture 0·1.

The points of divergence from *E. subgracilis* are, first, the greater width of the zoarium, viz. $\frac{1}{2}$ millim. instead of $\frac{1}{3}$ millim.; secondly, the more numerous zoœcia, five to a series instead of four. Furthermore the surface is transversely wrinkled and punctate. There are solid, irregularly perforated closures within the zoœcial orifice.

EXPLANATION OF PLATES XVII.–XIX.

Plate XVII.

Fig. 1. *Proboscina spatiosa*, sp. n., uniserial form. ×10.
2, 3. The same, ordinary form. ×10.
4. *Proboscina incrustans*, sp. n. ×10.
5. The same, gonœcium? ×25.
6. The same, zoœcia, flattened oœcia and ovicell. ×25.
7, 8. *Diastopora spatiosa*, sp. n., with capitulum of erect branch. ×6 & 7.

Plate XVIII.

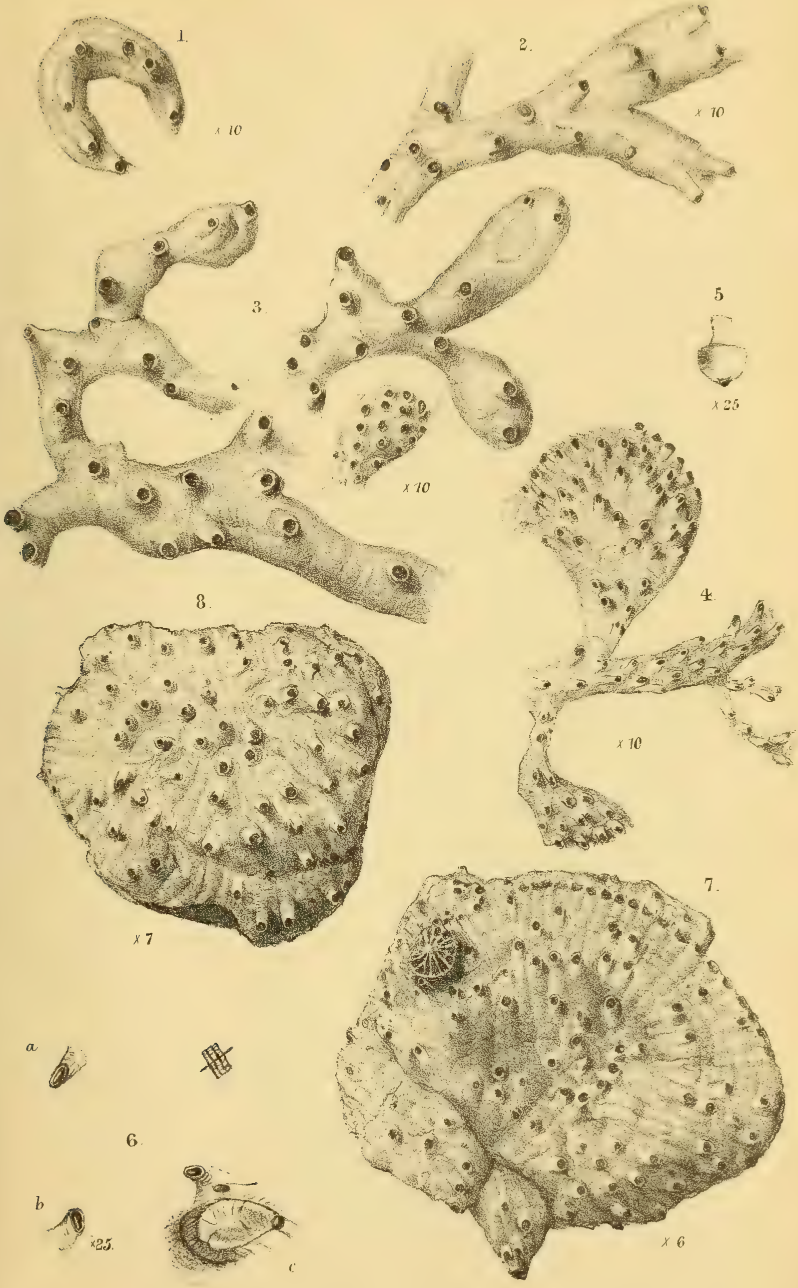
Figs. 1, 2. *Proboscina spatiosa*, var. *brevis*. ×12.
3–5. The same, var. *brevior*. ×8 & 12.
6 *a*. *Stomatopora spirata*, sp. n., ×6. 6 *b*. A portion, ×15.
7. —— *porrecta*, sp. n. ×25.
8. The same. ×18.
9. —— *dichotomoides* (d'Orb.), var. *attenuata*. ×15.
10, 11, 12. *Tubulipora spatiosa*, sp. n. ×10.
13. *Idmonea triquetra* (Lamx.), var. *Parkinsoni*. ×10.
14. *Entalophora subgracilis*, d'Orb., var. *corrugata*. ×10.

PLATE XIX.

Figs. 1, 2. *Idmonea claviformis*, sp. n. ×8.
3, 4. —— *triquetra* (Lamx.), var. Y-*formis*. ×10.
5, 6. —— *stomatoporoides*, sp. n. ×10 & 16.
7. *Bisidmonea tetragona* (Lamx.), var. *ovalis*. ×10.
8. The same, side view. ×12.
9. The same, with ovicell. ×10.
10. *Entalophora raripora*, d'Orb., transverse section. ×20.
11, 12. —— *magnipora*, sp. n. ×10.

DISCUSSION.

Dr. HINDE remarked that Mr. Walford had been fortunate in his discovery of such well-preserved examples of Polyzoa, and that he appeared to have worked them out in a thoroughly satisfactory way.



F. H. Michael del. et lith.

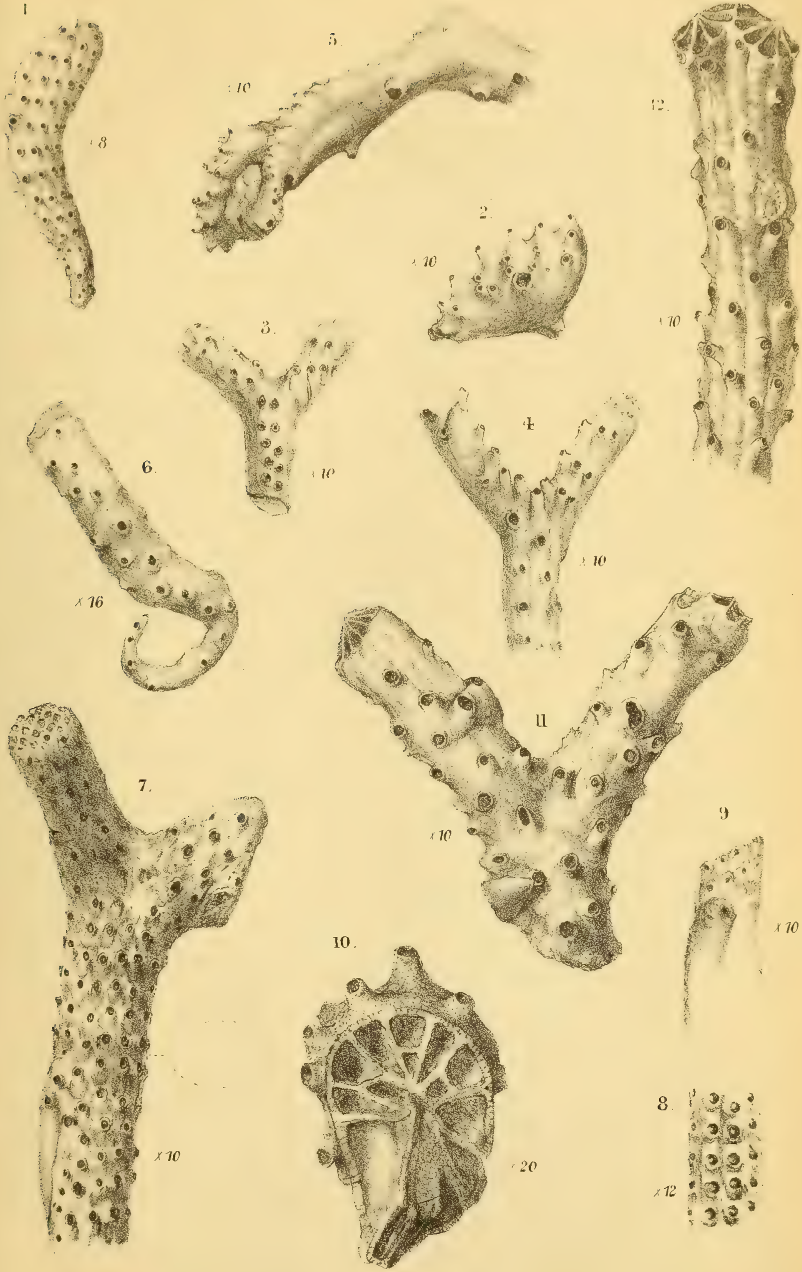
Mintern Bros. imp.

INFERIOR OOLITE BRYOZOA

F. H. Michael del. et lith.

Mintern Bros. imp.

INFERIOR OOLITE BRYOZOA.



F. H. Michael del. et lith.

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INFERIOR OOLITE BRYOZOA

36. *On the* Subdivisions *of the* Speeton Clay. By G. W. Lamplugh, Esq. (Read March 6, 1889.)

(Communicated by Clement Reid, Esq., F.G.S.)

Introduction.

Twenty years ago Professor J. W. Judd, in a paper * which has become classical, described to this Society the Clays which emerge from beneath the Chalk at Speeton on the coast of Yorkshire, and showed that they comprise the fullest development of marine beds of Lower Cretaceous or Neocomian age to be found in England; and, in a later paper †, he pointed out that the section at this place furnished the key by means of which might be identified the more or less isolated and fragmentary exposures of beds of this age scattered over the whole of the great North-European area. He showed, moreover, more clearly than had hitherto been done, that the uppermost beds of the Jurassic formation were also represented in the series, and defined the limits of the two systems.

In spite of the acknowledged importance of the section and the uncertainty which still pertained to parts of it, there has been practically no addition to our knowledge of the locality since these papers were published—the reason for this being, no doubt, the generally obscure and difficult state of the cliffs, as it is rarely, except in the winter or in stormy weather when this bleak coast-line has few visitors, that the conditions of the section are favourable for observation.

It needs a high and stormy tide, to reveal a fresh unweathered surface of clay at the foot of the slopes, or a heavy onshore gale, to sweep aside the sand and shingle of the beach, before the student of the section can make any really satisfactory progress either in collecting the fossils or in studying the sequence of the deposits; and many repetitions of such conditions are necessary before the many difficulties of the section can be grasped. For work of this kind, which can only be carried on at intervals, it is almost indispensable that the observer should live near the locality; and it is because of the opportunities I have had during the last ten years, by residence in the neighbourhood, that I have been able to accumulate the observations which I propose to summarize in this paper. Even now, as will be found, my knowledge of the section does not include quite the whole of the clays, but many more years might have elapsed had I waited to make it complete.

Bibliography.

The bibliography and history of the beds up to the date of publication of Professor Judd's first paper, in 1868, were thoroughly

* Quart. Journ. Geol. Soc. vol. xxiv. p. 219.
† *Ibid.* vol. xxvi. p. 326.

dealt with therein *, and the following are the chief additions to the literature of the subject since that time known to me:—

1869. MEYER, C. J. A. "Note on the passage of the Red Chalk of Speeton into an underlying Clay-bed." Geol. Mag. vol. vi. p. 13.

1875. Professor J. PHILLIPS. Geology of Yorkshire, 3rd ed. pt. i. (In this edition Prof. Phillips gave the result of his later researches at Speeton; and in a list of Yorkshire fossils, to be found in the same volume, several species are recorded for the first time from the Speeton Clay.)

1888. Explications des Excursions; Congrès Géologique International, p. 152. (In my description of the Speeton section in this guide-book, I briefly mention one or two of the points dealt with in this paper.)

Besides the above, there have been various incidental discussions of the section in different articles and memoirs, but I am not aware that in any of these have any new observations been recorded †.

PRESENT STATE OF THE SPEETON CLIFF-SECTION.

A few notes comparing the present state of the cliff with its condition twenty years ago will, I think, be found useful to anyone visiting the section or studying its literature.

The higher part of the cliff itself has, as Judd predicted, become more and more obscure, and the only portions in which any workable section may now be observed are the ridges lying to the north and to the south of Black Cliff.

The workings that were once carried on for the extraction of the "cement-stones" in one part of the cliff, and for "coprolites" in another, have long since been abandoned and obliterated—the latter having been suddenly and completely closed in 1869 by a great landslip, which, had it happened in the daytime, would have entombed the miners as it has done their tools.

With regard to the foot of the cliff, that portion lying to the southward, between Speeton Beck and the chalk precipices, has probably undergone little change, or it may even be better exposed than formerly, since clear though shallow sections of the clays may generally now be seen here under the slips of chalk and drift.

Along the foot of Black Cliff, also, there have been only slight changes, and the heavy slip of the clays mapped by Judd still persists, though the sea is gradually removing it, and sometimes reveals in it an excellent section.

Middle Cliff seems to have altered for the better, through the breaking away of some of the slipped drift which encumbers it, so that along its base there is generally now a continuous section of

* Quart. Journ. Geol. Soc. vol. xxiv. pp. 219 & 220.

† For some account of two important additions to the literature of the Speeton Clays since the above was written, see "note" at the end of this paper, p. 608.

the "*Noricus*-beds," and of the upper part of the "zone of *Belemnites lateralis*," and this constitutes one of the best collecting-grounds of the locality. These beds are puckered up into shallow folds.

The greatest change has taken place in New Closes Cliff, where the northern termination of the clays has been quite blotted out by the huge slip of drift which closed the "coprolite" workings. On the other hand, the sea has removed most of the talus heaps of the workings, so that the bituminous shales (Upper Kimeridge) are, for a short distance, well seen in the cliff-foot.

The Shore-exposures.

The beach off the clay-cliffs consists of sand with a little shingle, but as we go southward towards the great chalk-cliffs the flinty shingle increases rapidly both in quantity and in roughness, till it gives place to a rude pavement of loose blocks.

There is usually a rather steep slope of shingle with some sand, known to our fishermen as the "canch," near the foot of the cliff, and below this a broad flat belt of wet ripple-marked sand, which during neap-tides is scarcely uncovered, but during springs may attain a breadth of over 250 yards.

In stormy weather the sand forming this flat belt, instead of being spread evenly over the shore, is driven up into ridges, or is carried below the low-tide limit, leaving surfaces of the underlying clay exposed.

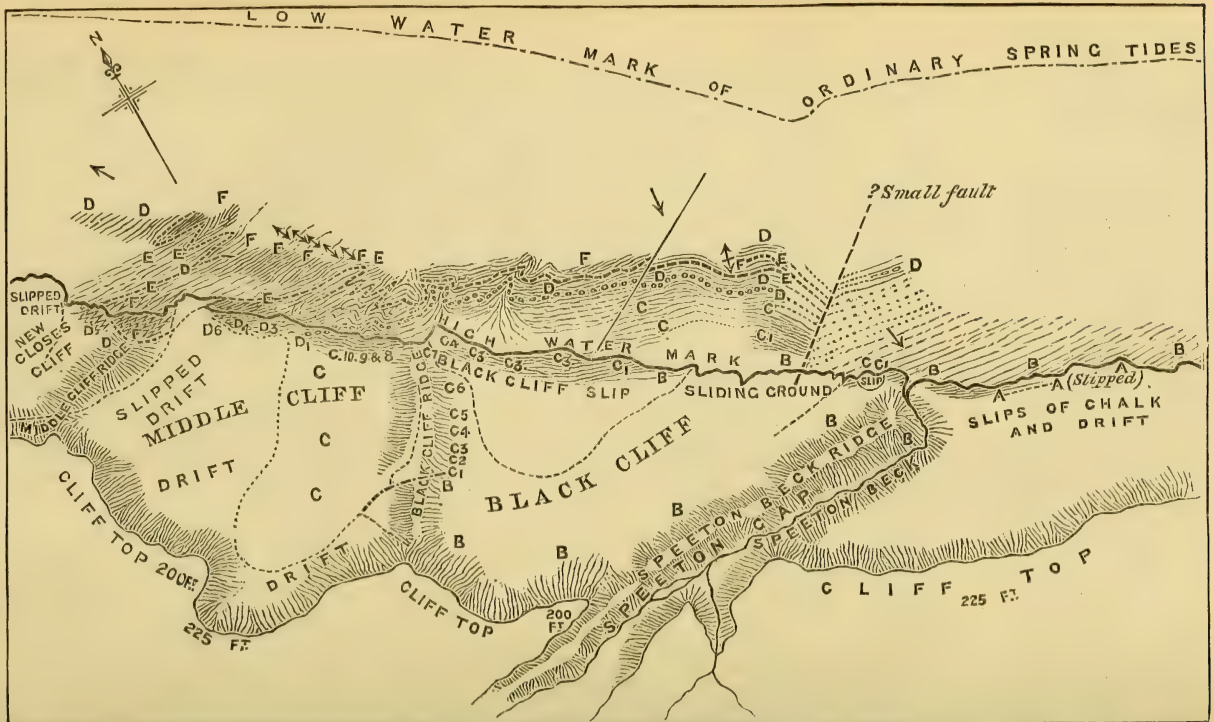
As the surface of this clay is some feet below the normal level of the sandy beach, when the beds are thus exposed, the breadth of the tidal flat is, of course, very much narrowed. Thus, in the accompanying ground-plan (fig. 1, p. 578), the broken line indicates the limit of low water as marked on the 6-inch Ordnance-map, while the seaward edge of the strata, as shown in the figure, is nowhere far from low-tide mark when the beach is thus denuded.

These exposures occur far more frequently over some portions of the beach than over others, and the "canch" itself is rarely broken through; but I believe that could a series of observations be carried on for long enough, the beds might be mapped over the whole of the shore. As it is, I have marked down on the ground-plan such strata as I have actually seen; and have connected these exposures by broken lines, which indicate the supposed extension of the beds where not yet observed.

That part of the shore which lies off the northern half of Black Cliff has of late years been far more subject to such denudation than any other portion. Consequently I have here had the greatest facilities for studying the beds, and my measurements and descriptions of the section have been chiefly made on this part of the section, where fortunately a fuller succession of the beds is shown than any other portion of the beach could reveal.

As this plan shows, the clays after emerging from beneath the chalk have a course that, though variable, does not at first present any marked irregularity; but a little further northward the beds

Fig. 1.—*Ground-plan of the Coast at Speeton, showing the Course of the Beds on the Shore and in the foot of the Cliff.*
(Scale 9 inches to 1 mile.)



A. Marly clays, with *B. minimus* &c. (slipped).
B. Clays of zone of *B. semicanaliculatus*?
C. Clays of zone of *B. jaculum*, Phil.
D. Clays of zone of *B. lateralis*, Phil.

E. Coprolite-bed - - - - -.
F. Bituminous shales with *B. Owenii* and vars.
o o o o Compound Nodular Band (D^1).

(The lines show the strike; where continuous, the beds have been actually observed; where broken, they are supposititious.)

become much disturbed and roll over in numerous short sharp folds. The general strike of the clays is about east and west, changing occasionally to south of east and north of west; and the general dip is southward at varying angles. The axes of most of the sharper folds run parallel to a broader anticline that crosses the beach and brings up the bituminous shales (Upper Kimeridge) into the cliff in New Closes Cliff.

The southward dip of the clays points towards the chalk escarpment; and their strike, even in the contortions, is generally more or less parallel to this escarpment. I think it is possible that the pressure of the chalk on these yielding clays may have affected their original arrangement, by causing an upward and outward creep from under the edge of the escarpment as it has been cut back.

Some of the minor contortions visible at the base of the slopes are probably due to the recent slipping of the cliff, as, for instance, those seen in the great slip of Black Cliff; and these slips may even have slightly displaced the beds on the shore. But the remarkable plications in Middle Cliff, which course nearly at right angles to the cliff-line, must be *at least* of older date than the Glacial Period, since there is no evidence of the disturbance in the glacial clays which cap the cliff, nor in the stratified shell-bed at the base of the drifts.

That the contorted beds just referred to form part of an anticlinal ridge, is clearly proved by the reappearance on the beach off New Closes Cliff (and probably also in the cliff itself), on the further side of the exposures of Upper Kimeridge shales, of the "Coprolite-bed" and the overlying clays of the zone of *Belemnites lateralis* * (see fig. 1).

These plications of the strata on the shore extend far northward, as I have seen the solid beds in Filey Bay, and they characterize all the exposures of the bituminous shales observed in places for nearly two miles from Speeton.

It has been suggested that these contortions affect only the Jurassic beds, and that the Neocomians may rest on the denuded edges of the contorted strata. The cliff-section has been thought to support this view; but I think it is only because in the southern part of the area, where the Neocomians are best shown, all the beds run without much irregularity, whereas where the Jurassic beds reach the cliff in the disturbed anticline they exhibit violent contortions, while the higher beds, which are really also contorted, are cut away or masked by the overlap of the drift.

At any rate the exposures on the shore show that where, as off Black Cliff, there is no serious disturbance of the Neocomians, the Jurassic shales are equally undisturbed; and where, on the contrary, as off Middle Cliff, the lower division is thrown into folds, the upper beds are also plicated. Nor is there any other evidence at Speeton for the supposed unconformity between the one portion of the section and the other, unless the mere fact of the presence of the

* This is confirmatory of the statement of Leckenby (as recorded by Judd, *op. cit.* p. 237), that the "Coprolite-bed" might sometimes be seen on the shore nearly as far north as Hunmanby Gap.

bed of "coprolites" be considered sufficient proof. I think therefore that the statement mentioned with some degree of doubt by Judd in the text of his first paper *, but brought more prominently forward in the "Comparative Table" of a later paper †, whence it has made its appearance in other quarters ‡, should be set aside as against the evidence.

That the Coprolite-bed should have been traced by Leckenby so far north as Hunmanby Gap shows that the average dip of the beds is not great—not perhaps greater than that of the chalk—and that the breadth of the outcrop of the bituminous shales cannot be taken as evidence of their thickness. They are probably repeated over and over again in the contortions. And as there are strong reasons for believing that the shales seen in the cliff near Filey, which have been supposed to represent lower beds ("*Middle Kimeridge*" and, on the shore, "*Lower Kimeridge*"), are not in place §, it follows that

* Quart. Journ. Geol. Soc. vol. xxiv. p. 237.

† *Ibid.* vol. xxvi. p. 330.

‡ *E. g.*, Survey Memoir of Country around Lincoln, 1888, p. 83 *et seq.*

§ Judd (*op. cit.* pp. 239 & 240) describes beds of sandy blue clay seen in the cliff about a mile to the south of Filey (*i. e.*, about three miles north of Speeton) under the title of Middle Kimeridge, and seems to have regarded them as in place. Phillips, however, refers to them as making "slight appearances at several detached points in and under the drift" (Geol. of Yorkshire, 3rd ed. pt. i. p. 103).

I have made careful examinations of these beds at intervals during several years, but have not yet succeeded in finding any of the Secondaries in place. The huge masses of shale which occur here at the base of the cliff and on the upper portion of the shore (the lower part of the shore I have not yet seen exposed here) are all "bouldered" in the Basement Clay, the lowest boulder-clay of the coast, one of whose characteristics is the frequent inclusion of masses of this kind. (See J. Phillips, Geol. of Yorksh. 3rd ed. pt. i. p. 85; J. Leckenby, 'Geologist,' vol. ii. p. 9, and Reports of Scarborough Phil. Soc. for 1854, p. 51; G. W. Lamplugh, Proc. Yorksh. Geol. and Pol. Soc. vol. vii. p. 244, for similar instances elsewhere.) These "boulders" when they reach down to the shore-line might sometimes be supposed to underlie the drift, but when the beach is removed at the cliff-foot the boulder-clay is seen to pass under them. They are generally lenticular in shape, and some of them, with the bedding still preserved, are tilted nearly on end, and run up into the drifts for 30 or 40 feet above high-water mark. The most conclusive and convincing proof of their transportation is furnished by the fossils with which most of them abound. I have collected the following species from masses of shale which lay in the cliff-foot with uninterrupted bedding-planes:—

Fossils from blue sandy Shale in the Drift near Filey.

Ammonites brevispina, *Sow.*	Pinna folium ?, *Y. & B.*
Belemnites clavatus, *Blainv.*	Pecten.
—— penicillatus, *Sow.*	Modiola.
Gryphæa cymbium, *Lam.*	Rhynchonella.
Plicatula (near to) spinosa, *Sow.*	&c., &c.

This list shows that the masses from which I obtained the fossils have been derived from the *Jamesoni-beds of the Lias*, with which they agree well in physical character.

Of course other masses may have come from different horizons, but I believe that all I have yet had an opportunity of examining are Liassic; and I do not think that beds occurring under such circumstances offer any safe indications as to the "solid" geology of the locality.

our actual knowledge of the Speeton section does not extend to any great depth into the Jurassic portion of the series *.

Supposed Fault in Speeton Gap.

It has been suggested that a fault of considerable throw may exist between the chalk and the main mass of the clays at Speeton, with a course coinciding nearly with the ravine of the Speeton Beck. But I think the supposed indications of a fault may be better explained by an ancient foundering of the chalk escarpment, possibly in pre-glacial times. I have seen the beach cleared off the Gap and for some distance both northward and southward, and could find nothing more important than a small break which seems to cross the beach slightly north of the Gap, as shown in fig. 1, and which is quite of minor consequence.

The Vertical Section.

As it is impossible to obtain a detailed section in the cliff, I have measured the succession of the beds on the shore as opportunities occurred; and though the difficulties met with on a sloping shore preclude the possibility of absolute accuracy, I am confident that the following sections, which are based on a long series of observations, give, where completed, the true sequence of the beds and approximate very closely to their true thickness.

In tabulating these sections I have not been able to adopt in its entirety the scheme of classification propounded by Judd, for reasons which will be given in full detail; but have found it easier to apply a new system of division based on the Belemnites. The lines of this division sometimes coincide with those already in use, and sometimes do not, as will be pointed out in my descriptions.

Belemnites is undoubtedly the most plentiful fossil of the clays, and occurs in the greatest profusion in nearly every bed above the Coprolite-bed. And though I am aware that these fossils are not usually considered desirable for stratigraphical purposes, yet in this case they are so palpably the natural guide to the section, that as such I have not scrupled to use them. As will be shown, they occur in well-defined species or groups, having on the whole well-defined limits corresponding to definite horizons in the clays and to marked changes in the fauna.

I propose therefore in this paper to divide the Speeton section in the following manner:—

A. Marls with *Belemnites minimus*, List., and allies.
B. Zone of *Belemnites semicanaliculatus* ? † and allies.
C. Zone of *Belemnites jaculum*, Phil., and varieties.
D. Zone of *Belemnites lateralis*, Phil., and varieties.
E. Coprolitic seam.
F. Bituminous shales with varieties of *Belemnites Owenii*, Pratt.

* In J. Leckenby's "Notes on the Speeton Clay" (Geologist, vol. ii. p. 9), we possess a valuable record of beds somewhat lower than any which have been recently exposed, but the details are unfortunately meagre (see diagram, fig. 2, facing p. 618, and note at p. 584).

† Adopting this specific name as used by Judd, for discussion of which see Appendix (p. 611).

These divisions I will now proceed to describe, commencing with the lowest.

F. *Upper Kimeridge.*

The lowest beds I have myself seen at Speeton, whether in the cliff or on the shore, are hard dark bituminous shales, finely laminated. These are best seen off Middle Cliff when the shore is uncovered, cropping out for over 150 yards in a series of sharp folds (see fig. 1). They may also often be studied in a low section at the foot of New Closes Cliff.

Southward they may, under favourable circumstances, be followed, underlying the higher clays, across the beach off Black Cliff, nearly as far as Speeton Gap, though for the greater part of this distance only the topmost beds are seen above low-water mark.

Northward from Speeton I have seen these bituminous shales in several places on the shore, especially off the neighbourhood of the village of Reighton.

These shales are nearly everywhere very fossiliferous, but the fossils are crushed between the laminæ in such a manner as to render their specific determination difficult. Ammonites in this condition are very abundant, and there are also many small bivalves. Belemnites are very rare, the shales in this respect being in marked contrast with the overlying clays. The few specimens of Belemnites that I have found, however, have all been in good condition and fine examples of their kind.

They are all closely allied to *Bel. Owenii*, Pratt, and have been determined as varieties of that species, thus supporting the expressed opinion of Phillips, Judd, and others, as to the Jurassic age of this part of the section *.

The folding and consequent repetition of these shales makes it a difficult matter to measure them on the beach, and the section given in fig. 3 (facing p. 618) is the only one I have obtained. Though incomplete, it will serve to show the character of the strata.

The nodules, which occur in bands in these shales, differ in many ways from those in the Neocomian beds. They are of large size, being in some bands from two to ten feet in diameter, and discoidal in shape, and they are composed of a palish blue limestone with strongly marked septa of yellow calcareous crystals. They seem to have been formed subsequently to the compression of the shales, as I have noticed cases in which a film of *crushed* Ammonites ran through these concretions, just as through the surrounding shale.

As will be seen from the fauna as given below, there can be no doubt as to the age of these beds, which thus give us a base to work from. They represent the 'Upper Kimeridge' of English geologists (see note at conclusion of this paper, p. 608).

The following species have been determined in my collection from these shales:—

* See Appendix, p. 610.

Fossils from the Bituminous Shales.

Ichthyosaurus ? (imperfect skeleton).
Ammonites biplex ?, *Sow.*
†Belemnites Owenii, *Pratt* *, and varieties.
†Alaria trifida, *Phil.*
†Cardium striatulum, *Sow.*
†Lucina minuscula, *Blake.*
†Ostrea gibbosa, *Lesueur.*
†Avicula, sp.
Discina latissima, *Sow.*
Lingula ovalis, *Sow.*
†Pollicipes Hausmanni, *Koch & Dunker.*

E. *The Coprolite-bed.*

Wherever I have seen the top of these bituminous shales, I have found them capped by a thin stony band of black phosphatized nodules, as shown in fig. 3.

This is the bed which was formerly mined in New Closes Cliff, and it is undoubtedly the "Coprolite-bed" of Judd, though not, I think, of Leckenby. It is referred to by Phillips as the "pebble-bed"‡. The average thickness of this band is only about 4 inches, a thickness which it preserves, along with its other characteristics, throughout the section with very slight variation.

Among the lumpy nodular material of which it is composed, one notices numbers of black phosphatic "pebbles," some of which glisten with a pyritous lustre. These are caked together in a matrix, probably partly phosphatic and partly aluminous, which yields to the weather and causes the crumbling of the bed. Many of the "pebbles" are subangular; others seem to have been the casts of shells or fragments of Ammonites; while some show a vague blurred resemblance to the bones of Saurians; but it is rarely that any fossils can be obtained in a recognizable condition, except occasionally Belemnites.

The outcrop of this bed in the cliff is hidden under a landslip, but I have followed it on the shore off nearly the whole length of Black and Middle Cliffs.

It is difficult to say whether the fossils which occur in this seam are indigenous to it or have been derived. The Belemnites, though much eroded and broken as though by long exposure on the sea-bottom and by subsequent pressure, are yet not usually imperfect, but show the whole length of the guard, and can scarcely, I think, be other than indigenous. They belong either to *Bel. lateralis* or to a closely allied species §. The other fossils have more the appearance of derivatives, but the sameness of character of the so-called pebbles is certainly remarkable. A list of these fossils so far as they are determinable will be found included in the table at p. 591, but it is not often that we can recognize more than the genus.

Similar black phosphatized stones occur scattered throughout the lower part of the overlying clays, sometimes sparsely, sometimes

* See Appendix, p. 610.

† These species are now recorded for the first time. I am indebted to Mr. T. Roberts for most of the above determinations.

‡ Geol. of Yorkshire, 3rd ed. pt. i. p. 102.

§ Professor A. Pavlow has recently stated that this Belemnite cannot be distinguished from a Russian "Lower Volga" species, *B. absolutus*.

more plentifully, and, as we shall presently see, in at least one other case they tend to accumulate in a stony layer. These, though as a rule smaller than those in the Coprolite-bed, seem to be the same in composition, and have probably had the same origin, whatever that may have been. And it seems to me that this coprolitic band may have been formed during a period when, either through the increased strength of the current, or through lack of material, or from some other cause, the deposition of the clay ceased and allowed time for the heavier nodular matters dropped over the sea-bottom to accumulate as a band.

This Coprolite-bed is undoubtedly a most important horizon in the series, both stratigraphically and palæontologically. There is a marked change in the character of the deposits almost immediately above it, and also in the fauna. Indeed, of the few Jurassic forms which pass it, the doubtful *Lingula ovalis* is the only species yet found in the bituminous shales, though our limited knowledge of their fauna deprives this observation of much force.

When we turn to Judd's section *, we find that between the bituminous shales (Upper Kimeridge) and this Coprolite-bed he intercalates a set of beds of Portlandian age, which are stated to consist of, first, a "peaty clay with fish-remains," and, below this, layers of "dark-coloured clay with hard stony bands," containing well-preserved Ammonites of the coronated type. The correlation of these strata with the Portlandian rests chiefly on these Ammonites.

Judd does not give the thickness of these beds, and says expressly that he did not himself see them, but had had his account of them from Leckenby.

These "coronated" Ammonites are to be found in all the old collections made at Speeton, but it is now very difficult to obtain them, so that for a long time I could not make out whence they came. I could find no beds among those I had examined below the Coprolite-bed in which there was any probability of their occurrence, the mode of preservation of these highly inflated forms being totally different from the compressed character of all the remains in the bituminous shales, wherein, as already stated, the fossils are flattened out even when included in the nodules. At length, however, during an exposure last autumn, I detected traces of them in the clays of the *Lateralis*-zone at some distance *above* the Coprolite-bed, and following this clue, soon succeeded in finding a good specimen at this horizon. This caused me to re-examine the evidence on which was based the statement that these fossils came from below the Coprolite-bed, and in doing so I compared my own section at Speeton with that of Leckenby † and with Judd's. It then became evident that what

* *Op. cit.* p. 231.

† J. Leckenby, 'Geologist,' vol. ii. p. 9. This paper extends to barely three pages, but contains a detailed section of part of the clays, with lists of many of the fossils. These lists are somewhat misleading, since many of the commoner fossils are omitted, and often only the rarer forms (recorded under little-known names) are mentioned; indeed it is probable that the section has been originally compiled more as a guide to the collection of the rarer fossils than as a serious attempt to describe the strata. The sequence, however, is accurately given, and the paper is of great value for comparison.

Leckenby meant by the "Coprolite-band" was not the same horizon as the "Coprolite-bed" of Judd, that he indicated by that name the very striking layer of limestone-nodules with scattered coprolites, presently to be described in this paper as "the Compound Nodular Band."

The existence of this higher band was apparently unknown to Judd, who seems to have had no doubt that the bed mentioned by Leckenby was the one known to him. However, as Leckenby's section and my own researches show, the coronated Ammonites really occur in the hard pyritous clays which Judd himself saw and, not knowing this, described as the "Zone of *Amm. Astierianus*." And thus it happens that the "Portlandian" of Leckenby is part of the "Lower Neocomian" of Judd, and the hypothetical beds placed by the latter author below the lower Coprolite-bed have no existence.

In the diagram (fig. 2, facing p. 618) the section given by Leckenby is arranged side by side with Judd's and my own, so as to show these results.

D. *Zone of* Belemnites lateralis, *Phil.* (fig. 4).

Though I have described the Coprolite-bed separately because of the importance attached to it by previous authors, there is really not much reason for separating it from the overlying clays, of which it may be considered as the base.

Immediately above the "Coprolite-bed" we have about 10 inches of hard blackish shale (*D* 8), which does not differ much in appearance from the bituminous shales below (F), so that Leckenby's description of this "Coprolite-bed" as "a seam of coprolitic nodules" in a "stratum of dark brown shaly clay" (Bed 6 of his section) is really justified.

In this shale I have not detected any fossils except a fragment of bone and a few greatly eroded specimens of Belemnites. These latter are beyond specific determination, but what is left of them shows that they are not far removed from *B. lateralis*; if not actually of that species, they must, like those in the Coprolite-bed, belong to an allied form.

In the overlying band of greenish-black shale undoubted specimens of *Bel. lateralis* can be readily identified. From this point the species occurs abundantly, and remains predominant up to the Compound Nodular Band. Figure 4 gives the detailed section of the zone from top to bottom.

The only other fossils I have noticed in the band are a few shells in a fragmentary condition; but the bed also contains a thin sprinkling of small black pebbles, probably phosphatic, generally not larger than peas.

The variegated and banded clays which lie above serve as passage-beds into the very conspicuous pale band (*D 6*), which forms a striking feature in the section. In the latter bed the clay towards the centre of the band becomes very firm and hard—indeed Leckenby, who noticed the "remarkable line of demarcation" which the bed makes, describes it as an "argillaceous stone." It is curiously mottled, in its lower part especially, with flattened tubular

markings in various tints of grey, green, blue, and brown, showing dark in the paler beds, and pale in the darker. In a thin seam at the base of the band this structure is particularly well developed, the markings being of a bright blue colour on a dark blue ground. Many beds higher in the section show the same peculiarity, though not often so definitely.

Small black coprolitic "pebbles" occur sporadically throughout this band. *Belemnites lateralis* abounds, sometimes attaining a large size, and both large and small specimens are excellently preserved. The other fossils, chiefly bivalves, are, however, in the form of soft crushed casts, and though they are by no means rare, there is great difficulty in obtaining determinations of them.

Similar though usually somewhat less conspicuous bands of pale blue or grey clay constantly recur in all parts of the series at Speeton, as will be seen from the other sections. These pale clays are always tougher than the dark beds, and do not so readily splinter or "shale." They probably contain a larger amount of lime, and nearly always show a tendency to develop bands of nodules. These nodules are sometimes small ovoid or potato-shaped masses with a soft brown exterior but hard and dark within, with crystals of selenite and pyrites lining thin septa; or they form much larger irregular masses of hard pale blue or grey limestone, generally with strongly marked septa of yellowish calcite. The "potato-nodules" do not, as a rule, contain fossils, but the limestone septaria at certain horizons often include large but generally imperfectly preserved specimens of *Crioceras* (*Ancyloceras*) or *Ammonites*, and sometimes other fossils also.

In the dark clays *D 5*, which succeed the pale blue bed, fossils are rare, but the horizon is characterized by the relative abundance of a *Lingula* (*L. ovalis*?), and we might therefore name it the *Lingula*-bed. *Belemnites lateralis* occurs in this bed in a curiously decayed state, the exterior being deeply eroded, while the interior, instead of showing the usual clear horn-like appearance, is quite opaque and white.

A thin pale band separates the *Lingula*-bed from the next division of importance. This is a thick bed of splintery brownish clay (*D 4*), very full of pyrites disseminated through the mass in minute crystals and groups of crystals, which from its thickness and the abundance of its fossils is the chief member of the zone. Yet though fossils are here so plentiful, especially in the upper part of the bed, it is only when the clay is examined in a fresh exposure on the shore or at the foot of the cliff that this becomes evident, as the rapid decomposition of the pyrites coats the weathered surfaces of the bed with a whitish efflorescence, and rapidly destroys all except the coarser forms. During the process fine crystals of selenite are sometimes produced.

Judd has described these beds as the "zone of *Amm. Astierianus*," but I have not yet been able to detect any undoubted specimen of that species in any bed within the zone of *Bel. lateralis*. A small

species, not yet determined, but which I am informed is not *Amm. Astierianus*, is common in the bed just described *. Varieties of *Exogyra sinuata* occur in profusion, and, among other shells, an *Astarte* named by the early collectors *Astarte senecta* is very abundant; and as this shell is rare everywhere except in these pyritous clays, we might for convenience of reference speak of them as the "*Astarte*-beds."

The fossils of the *Astarte*-beds as at present determined will be found separately indicated in the table at p. 591. Many additions might be made if the specimens could be identified without removal.

Softer pale brownish and striped beds (*D 3*) succeed, containing most of the fossils of the underlying beds.

In addition, one of the "coronated" Ammonites (*Amm. Gravesianus*, D'Orb.) occurs in a nodular band. The shell seems to be plentiful in this band, but it is generally badly preserved; so that though I have found several casts of the deep umbilicus, which form curious long spirals, and other fragments, I have obtained only one good specimen. The position of this Ammonite-bed on the beach is marked by a water-channel, a feature that may be owing to unequal erosion of the clays, though it is quite as probable that it has been caused by raids made on the band by the early collectors, who evidently set great store by these beautiful Ammonites, and who were quite capable of scooping out the bed in their searches, just as they have served the famous plant-bed in the Oolites at Gristhorpe. Leckenby, it will be noticed, who made a large collection of these forms, has recorded the fossil from this horizon under the names *Amm. quadrifidus*, Bean, and *Amm. cavaticus*, Bean (see diagram fig. 2).

The thin band of clay with nodules which caps these striped beds includes here and there lenticular masses of soft gritty ferruginous stone. Higher in the section these ferruginous stony bands are frequent, and more persistent in character, and are a distinctive feature of that portion of the clay; but this is the only example of this structure I have observed in the zone of *Bel. lateralis*.

Dark blue or brownish clay about 4 feet thick lies above this band and reaches to the top of the zone. This clay (*D 2*) is slightly gritty in texture and contains a quantity of dark green and black grains, probably of glauconite. It is crowded with *Bel. lateralis* and some other fossils, and has a plentiful sprinkling of brown "potato-nodules" and black and brown coprolitic stones. These latter become more abundant towards the top, and of larger size than anywhere else in the section. One lump measured 3 inches $\times$ 2 $\times$ 1, and I have seen others even exceeding this. Some of these stones, especially the larger ones, occasionally present a striking peculiarity in being on some sides quite angular. Usually they are more or less rounded and curiously eroded, as though by marine organisms, and are sometimes pitted by tubular holes that look like *Pholas*-borings; but it is not

* Prof. A. Pavlow has recently stated his belief that these small forms may represent species well known in Russia as *Olcostephanus subditus*, Traut., and *Oxynotyceras catenulatum*, Fisch. (see note at p. 608).

uncommon to find a stone presenting this worn appearance in one portion cut suddenly across by a sharp-angled fracture, of which the face is apparently quite fresh and unworn. The stones often have a distinct tendency to break into cubical fragments after the fashion of septaria; but I have satisfied myself that in the cases I have just described the fracture has not taken place as the stone lay in the clay, but that it was deposited there in this imperfect condition. In one instance one of these semi-angular stones, $3\frac{1}{2}$ inches in length, formed part of the outer whorl of a large Ammonite resembling *Amm. biplex*, but in no other case have I found any indication of fossils in them. These stones are still more plentiful just above, in the compound nodular-band (*D 1*). It is not easy to understand how pebbles of this size with unworn angles could be deposited in fine clay, and I shall revert to the matter in a later portion of my paper.

Imbedded in the upper portion of this clay is the very clearly-marked line of curious nodules (*D 1*) which forms a peculiar feature of the section. The smaller of these nodules are of the usual oval, brown character; but these are subordinate to larger concretions, evidently of a later growth, which form large irregular flattened-oval masses of limestone of a pale grey or bluish tint. These masses generally surround and include several of the smaller "potato-nodules" along with black coprolite-stones and fossils of various kinds. In some cases an examination shows that the smaller nodules with their black pyritous interior and brown outer coating have not only been completely developed, but have also suffered a certain amount of marine erosion before the concretionary action recommenced which formed the large limestone masses.

Nevertheless, this renewal of the concretionary action has not taken place at a later date than the formation of the seam. It is evident that the deposition was at this period extremely slow, and thus allowed the action to take place contemporaneously, since the larger masses themselves often show distinct signs of weathering and decay as though they had been exposed on an open sea-bottom. The whole aspect of the seam as well as the evidence of the fossils indicates a pause in the deposition of the series. There is, however, not the slightest sign of an unconformity.

Belemnites lateralis occurs in large numbers both in the nodules and in the clay surrounding them; but here the species abruptly dies out, and I have not found any specimen of this species in higher beds. Its place is taken by *Bel. jaculum*, which sets in suddenly and abundantly just above the nodules and reigns supreme and all but alone throughout the succeeding 120 feet of clay. There may be a slight intermingling where the two meet, as their horizons seem somewhat to overlap, though it is rarely that one can find them actually together. It is possible that the guards of *Bel. lateralis* may have lain exposed for some time on the sea-bottom like some of the nodules, and the occasional intermingling need not necessarily indicate that the two forms were alive together in the same

waters. It seems as though, during the slow formation of this bed, some physical change had taken place which rendered the area unfit for its former occupants and permitted a sudden and vigorous invasion of fresh forms from other waters.

With *Belemnites jaculum* appears *Ammonites noricus*—or, rather, the Ammonite immediately precedes the Belemnite, for it is found in abundance in the Compound Nodules associated with *B. lateralis*, though not lower. Like *B. jaculum*, it comes in quite suddenly, and seems almost immediately to attain its maximum development with respect both to size and numbers. About a foot above the nodules there is an almost continuous layer of large Ammonites apparently of this species, badly preserved as soft impressions in the clay, some of them measuring considerably over a foot in diameter. In the higher beds of its range it is rare to find *Amm. noricus* exceeding two or three inches.

The Compound Nodular Band is one of the best, if not *the* best horizon for fossils in the whole section. Remains of Saurians are comparatively so abundant in it that within the space of the short outcrop which can be examined I have thrice found a mass of bones indicating the occurrence of a more or less complete skeleton. Large specimens of *Ammonites* (other than *Amm. noricus*, but as yet undetermined) and *Crioceras* also occur in the larger concretions. This is the lowest level to which I have traced the last-named genus, so plentiful in the overlying beds.

At page 591 will be found a list of the fossils already recognized from the zone of *Bel. lateralis* (including "the Coprolite-bed"), in which also are indicated those found in the Compound Nodular Band and the surrounding clay.

That this Compound Nodular Band is the same as Bed No. 9 of Leckenby's section is placed beyond doubt by the fossils that he gives from the beds above and below; *Bel. jaculum* and *Amm. regalis* (=*Amm. noricus*) in the one position, and *Gryphœa sinuata* (=*Exogyra sinuata*) and *Astarte sinuata*, Bean (evidently a misprint for *Astarte senecta*), are conclusive on this point. And it is equally clear that it is to this band, and not to the true Coprolite-bed, that Leckenby refers in his note in Dr. T. Wright's 'Monograph' * as a "band of pseudo-coprolites" forming a "line of demarcation" "distinct and clear" between the Jurassic and Cretaceous parts of the section.

The question therefore now arises, whether the beds in which the coronated Ammonites are found should be relegated to the Portlandian. If so, we must follow Leckenby in tracing the division between the Lower Cretaceous and the Jurassic at the Compound Nodular Band. But by so doing we include clays containing a few species which are not usually recognized as Jurassic, such as *Belemnites lateralis* and *Exogyra sinuata* †.

* Mon. Brit. Cret. Echinod. pt. i. p. 9, Pal. Soc. xxi.

† It will be noticed that *most* of the Neocomian species given in the list at p. 591 have been found only in the Compound Nodular Band, and not lower.

While my own researches fail to reveal any break in the strata at this horizon, which I regard rather as a passage-bed in which the two faunas meet, wherein there is necessarily a mingling of types, as shown by the occurrence of *Bel. lateralis* and *Amm. noricus* in the same nodules, they are yet distinctly favourable to Leckenby's view that the clays up to this point may be included with the Jurassic. The addition of *Pecten lens*, Sow., var. *Morini*, De Lor., and *Avicula inæquivalvis*, Sow., to the list of Jurassic forms previously determined, strengthens the case in one direction; while my failure to find *Amm. Astierianus*, D'Orb., and some other Neocomian fossils which have been said to occur in this part of the section has the same effect in another way, by weakening the evidence on which the beds have been referred to the Neocomian *.

Should the Jurassic age of these *Lateralis*-beds be considered as established, I would point out the important bearing which this alteration of the Speeton section will have on the beds elsewhere in England and Northern Europe that have been correlated with it. In the lists of fossils from these other localities (*e. g.*, the numerous ones given in Judd's later paper †, or those in the recently printed Survey Memoir on the country around Lincoln ‡) one constantly notices *Bel. lateralis* along with *Bel. jaculum* and the other Neocomian species. It would become necessary to revise these lists and find out what forms are truly associated with *Bel. lateralis* and what occur in higher beds, so as to discover whether in other regions also it may be advisable to draw the upper limit of the Jurassic higher in the series.

It may be well to mention in this connexion that in the upper beds at Speeton, in the zone of *Belemnites semicanaliculatus* ?, there is one form among the varying types of Belemnites which there occur that bears a close resemblance to *Belemnites lateralis*, and has sometimes been referred to that species. Close examination of a large number of specimens, however, has convinced me that they are quite distinct. Where this form occurs alone it might easily be mistaken for the true *Bel. lateralis*, and this might lead to an erroneous classification of the beds, supposing the respective horizons of the fossils to be as at Speeton.

* By far the most important evidence yet adduced as to the age of these beds has been furnished since this was written by the Russian geologists Prof. A. Pavlow and M. S. Nikitin, who show that they are the equivalents of the "Upper-Volga beds" of Southern Russia: see note at end of this paper (p. 608).

† Q. J. G. S. vol. xxvi. pp. 326–347.

‡ Survey Memoir: On the country around Lincoln, 1888, pp. 82–104.

Fossils of the Zone of Belemnites lateralis, *Phil.*

	'Coprolite-band.' *E.*	Blue Beds. *D6.*	*Lingula*- and *Astarte*-Beds. *5&4.*	Striped and Dark Clays. *3 & 2.*	Compound Nodular Band. *1.*	Higher beds.
Belemnites lateralis, *Phil.*	?	*	*	*	*	
—— (absolutus, *Fisch., see Pavlow*[1])	*					
Ammonites Gravesianus, *D'Orb.* ...	...	...	*	*		
—— noricus, *Schloth.*, and varieties	...	...	...	...	*	*
—— rotula, *Phil.* (kaschpuricus, *Traut., see Pavlow*[2])	...	...	...	...	*	*
—— sp. (*cf.* subditus, *Traut., see Pavlow*[3])	...	...	*	*		
—— sp. (fragments)	*					
—— sp. (fragments)	*	...	...	* "pebble."		
—— sp.	...	*				
Crioceras (Ancyloceras), sp.	...	...	...	...	*	*
Aporrhais, sp.	...	...	...	...	*	*
Avellana (Auricula) obsoleta, *Phill.*	...	...	...	*		
Ostrea, sp.	...	...	...	...	*	*
Exogyra sinuata, *Sow.* (Couloni, *D'Orb., of Judd*)	...	...	*	*	...	*
—— ——, var.	...	...	...	*		
——, sp.	...	...	...	...	*	*
Plicatula, sp.	...	...	...	...	*	*
†Avicula inæquivalvis, *Sow.*	...	...	?	...	*	
Arca, sp. (casts)	*					
Nucula, sp. (ovata *of Leckenby*[4]) ...	...	*	*	*		?
——, sp. (subrecurva *of Leckenby*[4])	...	...	*	*	...	?
Lucina portlandica ?, *Sow.* (casts)...	*					
Astarte senecta, *Bean, MS.*	...	...	*			
Panopæa (plicata ?, *Sow.*)	...	*	*	*	*	?
Thracia (depressa *of Leckenby*)	...	*	...	*	*	
Pholadomya (decussata, *Phil., of Leckenby*)	...	?	...	?	*	*
Terebratula (? subundata *of Leckenby*)	...	*	*	...	*	
Rhynchonella, sp.	*					
—— inconstans ?, *Sow.*	...	...	...	...	*	
Lingula ovalis[5] ?, *Sow.*	...	...	*			
†Pecten lens, *Sow.*, var. Morini, *De Lor.*	...	...	*	...	*	*

† These species are recorded for the first time.

[1] A Pavlow, 'Études sur les Couches Jurassiques et Crétacées de la Russie' (Moscow, 1889), p. 43.

[2] *Op. cit.* p. 45, and plate.

[3] *Op. cit.* p. 46.

[4] 'Geologist,' ii. p. 9.

[5] *Lingula ovalis* ?, Sow. The species abundant in the *Lingula*-bed *D 5* was at first doubtfully referred to *Lingula truncata*, Sow., but a later opinion indicates that it is close to *L. ovalis*, Sow.; and as it occurs in that portion of the section which has Jurassic affinities, I have preferred to use the latter name. It is, however, a larger shell than the species in the bituminous shales, which is always small.

List of Fossils (continued).

	'Coprolite-band.' E.	Blue Beds. D 6.	*Lingula*- and *Astarte*- Beds. 5 & 4.	Striped and Dark Clays. 3 & 2.	Compound Nodular Band. 1.	Higher beds.
Pecten cinctus, *Sow.*	...	...	?	...	*	*
Serpula (articulata, *Sow.*, *of Judd.* = S. vertebralis *of Leckenby's list*)	...	*	*	...	*	*
—— antiquata ?, *Sow.*	...	...	...	...	*	*
Pentacrinus annulatus ?, *Römer*	...	...	...	...	*	*
Meyeria ornata, *Phil.*	...	...	...	...	*	*
Cidaris (spine)	...	...	...	...	*	
Fish (vertebræ and teeth)	...	...	...	...	*	
Saurians	...	...	...	...	*	
Coral (growing on *Serpula*)	...	...	...	...	*	
Lichenopora	...	...	...	...	*	

NOTE.—In these lists where the specific name is placed in brackets, it indicates that, though the fossil is in my collection, the determination is that of a previous author which has not yet been confirmed.

C. *Zone of* Belemnites jaculum.

I have already described the incoming of this Belemnite with its accompanying Ammonite (*Amm. noricus*, Schloth.). With these fossils we reach a stage of which the Lower Cretaceous or Neocomian age is beyond dispute, though there are still two or three bivalves in the lowest beds of the zone which seem to be Jurassic species, as might be expected from the conformable nature of the passage. From this point upwards there has been a steady and apparently uninterrupted accumulation of clay, and an equally steady advance of the fauna.

Belemnites jaculum ranges through about 120 feet of clay, and throughout this thickness I have seen but a single specimen of a different species. The solitary trespasser, which was found in the upper part of the *Noricus*-beds, is a deeply grooved Belemnite, not rare in the upper division (*B*) of the series.

Amm. noricus has not nearly so extended a range as *B. jaculum*, dying out after tenanting less than 30 feet of the zone, and giving place to *Amm. speetonensis*, Y. & B., which, in its turn, shows up strongly through the succeeding 30 feet and then becomes very rare, though it does not actually disappear till we come very nearly to the top of the zone. These Ammonites thus mark convenient subdivisions, and have been used by Judd for that purpose.

The section, fig. 5, gives the full extent of the zone and shows these subdivisions. It is the result of repeated measurements on the shore off Black Cliff, to a great extent checked and corroborated

by examinations under favourable circumstances of the cliff-foot lying opposite and to the northward *. Since this Belemnite and the forms grouped around *Bel. semicanaliculatus* divide between them the Lower Cretaceous part of the section, we might, if the term Neocomian is to be retained in use, appropriately name this zone the Lower Neocomian, and if not, the Lower Speeton Beds; and the overlying beds the Upper Neocomian or the Upper Speeton Beds. In doing so, we omit the term Middle Neocomian altogether; but I shall show that this term cannot satisfactorily be applied at Speeton.

I think the description which Judd has given of the range of this Belemnite needs some correction, as the fossil is nowhere more plentiful than in the *Noricus*-beds (in which it has been said to be very rare), and in its upward range, soon after passing the base of the *Speetonensis*-beds, though still common enough, it becomes decidedly less abundant.

Amm. noricus-*beds*.—The range of *Ammonites noricus*, which, as I have stated, commences with the Compound Nodular Band, thus just overlapping into the zone of *Bel. lateralis*, consists, as my section shows, of alternating bands of dark blue and pale blue clays, the dark beds on the whole predominating. Nearly all these clays contain the small brown-coated "potato-nodules," which are not usually fossiliferous. The clays themselves, however, are often rich in fossils.

The dark clay (*C 11*) immediately overlying the Compound Nodular Band is gritty, and full of dark green and black grains (glauconite), which tend, towards the top, to form a distinct seam. This bed is very fossiliferous, some of its bedding-planes being crowded with specimens of *Avicula*, *Pecten*, *Ostrea* (small species), *Lima*, *Leda*, and other delicate shells, which will scarcely bear removal and are therefore for the most part as yet undetermined.

Somewhat higher in the zone (*C 9*), the clays are characterized by the abundance of a small shell known in our Yorkshire museums under the MS. name of *Inoceramus venustulus*, Bean, which, so far as I know, is peculiar to this portion of the section.

In one of the nodular bands of this zone, that at the base of one of the pale seams in *C 9*, many of the nodules, instead of being of the usual rounded oval shape, assume a flattened outline, and these are generally found to enclose specimens of *Meyeria ornata*, Phil., or other crustacean remains. This does not seem, however, to be the horizon known to early collectors as the "Shrimp-bed," as Leckenby and Judd agree in placing that bed higher in the series; but the fossil has a wide range and may occur anywhere within the zone of *Bel. jaculum*.

It is not easy to define the exact upward limit of the *Noricus*-beds on the shore, as the fossil becomes somewhat rare in the uppermost layers; but I have not found it above the lower of two well-marked bands of rather large nodules distinguished by

* A good general knowledge of the sequence of the beds in this zone may be gained on the ridge between Black and Middle Cliffs, nearly the whole of its thickness being there shown, though in places obscurely.

the great abundance of specimens of *Crioceras*. The space between the two bands is held by dark clay in which a variety of *Amm. speetonensis* is tolerably abundant.

In these nodules, the Crioceratites are not very large, but in a third bed $4\frac{1}{2}$ feet higher, in which here and there lenticular masses of ferruginous stone are developed, the specimens are of a different species, and often very large in size.

In the list given at p. 597 the fossils of the *Noricus*-bed will be found separately indicated. It will be seen that several other species of Ammonites occur, but *Ammonites noricus* is throughout clearly predominant, the other forms being represented only by rare and scattered specimens.

Amm. speetonensis-*beds*.—This variable and difficult species makes its first appearance, as just mentioned, in the band of clay between the two nodular *Crioceras*-bands. The variety found here has very coarse ribs and is an extreme form of *Amm. concinnus*, Phillips; a little higher in the section it is accompanied, and in great part replaced, by the fine-ribbed variety *Amm. venustus*, Phil. The species speedily attains its greatest development, being most abundant in a thick bed of dark splintery shaly clay (*C 6*), where it is surrounded by a well-preserved and extensive fauna.

Above this fossiliferous bed we have a considerable thickness of banded clays, alternately pale and dark blue, but with the dark tint predominating, in which fossils of any kind are rare, though *Bel. jaculum* may be traced throughout. The beds of this horizon are not often exposed on the beach, and their outcrop in the cliff-foot is hidden by the great slip in Black Cliff, so that opportunities for studying them are rare; but I have seen them several times, and can confirm Leckenby's statement that they are sparingly fossiliferous. I have not yet found *Amm. speetonensis* in them, but it is probably not absent, as it is of frequent occurrence higher in the section.

A marked feature in the clays from the base of the *Speetonensis*-beds upwards to the top of the zone of *Bel. jaculum*, and for some little distance beyond, is the frequent recurrence of irregular lenticular beds of indurated ferruginous marl- or clay-stone, which form along nearly every line of nodules. These hard bands form miniature broken reefs of greyish stone in the shore-exposures; but in the cliff they weather down into a red stain, which may be seen in conspicuous bands along the south side of the ridge separating Black Cliff from Middle Cliff. In Lincolnshire, as is well known, there is a great development of workable ironstone of this age.

Supposed "Middle Neocomian."—I am inclined to think that the beds above *C 5* of fig. 5 fall within the range of the Middle Neocomian of Judd, who defines the base of this division as being formed by the "*Ancyloceras*-beds," described as dark blue clays, the metropolis of *Bel. jaculum*, with regular layers of septaria, and in which *Ancyloceras* attains the maximum of abundance. This description applies best to the above-described *Crioceras*-beds at the top of the

Noricus-beds, at which horizon also Leckenby, it will be noticed, has placed his "great band of *Hamites*" (see fig. 2). Judd, however, has indicated also in his section a lower band with *Ancyloceras*, agreeing well in position with the bed just named, so that his true "*Ancyloceras*-beds" may occur higher up among the sparingly fossiliferous clays, where as yet I have not been able to recognize them. At any rate, above these clays with few fossils we reach a series of dark gritty clays with green glauconitic grains, alternating with pale nodular bands (*C 4*), in some portions of which fossils again become plentiful, and these, it is clear, must be well within Judd's "zone of *Pecten cinctus*" ("Middle Neocomian"). We here find, along with *Bel. jaculum* and the small *Ammonites nucleus*, numerous large bivalves of the Oyster family, but the shells are so much crushed and disintegrated that it is rarely these can be identified. *Vermicularia Sowerbyi* appears for the first time in the upper layers of these clays, and I have obtained shattered examples of a very fine *Pleurotomaria* from the same horizon, along with some smaller Gasteropods, Rhynchonellæ, and other shells, and many Crustacean remains; but it is very difficult to obtain determinable specimens of the characteristic *Pecten*, which, except when preserved in nodules, is crushed to fragments. I do not see what there is in the fauna of these beds that led Judd to adopt the term "Middle Neocomian" for them, except *Pecten cinctus*, which was taken as one of the most typical fossils. This shell, however, is by no means confined to these beds (as Judd himself admits), nor is it in any way peculiar to them, and the only really fine example I have obtained of it at Speeton (a perfect specimen eight inches across) occurred *in the Compound Nodular Band*. It is stated also that in some foreign localities this shell is found in the *Lower* Neocomian *; and I have myself found it associated with *B. lateralis* in Lincolnshire.

Moreover, as I shall show that in the bed immediately overlying these clays several of the Lower Neocomian Ammonites reappear, along with other Lower Neocomian types, it seems scarcely possible to establish the "Middle Neocomian" in this part of the section. Nor do I see to what part of the Speeton section the term can with any degree of utility be applied, since in descending from the "Upper Neocomian" to the top of the zone of *Bel. jaculum* there does not seem to be any palæontological break either at the "cement beds" or elsewhere, but, rather, a gradual change of fauna throughout, as shown by the overlapping ranges of many of the typical species.

The Echinospatangus-*bed, C 3*.—Next above the dark gritty clays we reach the bed in which, as just stated, the "Lower Neocomian" forms reappear. This forms a band of pale blue clay, fully eight feet thick, with a conspicuous pale yellowish or greenish-grey stony layer at its base weathering red in the cliff, which can be best examined at the cliff-foot in the great slip in Black Cliff. It may

* Judd, Q. J. G. S. vol. xxvi. p. 345, footnote.

also readily be traced, in places, high up on the ridge between Black and Middle Cliffs, and I have seen it in exposures on the shore. The clay is very tenacious, and, besides showing many smaller concretions scattered irregularly here and there, includes a band of rather large pale brown nodules. Towards the centre it becomes browner in colour, and contains numerous small pellets of fine-grained iron pyrites, which, when closely examined, are often found to encrust small Echinoderms. The bed cannot be described as very fossiliferous, but it contains a fair number of small well-preserved specimens, and a close search reveals a considerable and interesting fauna.

The smaller slender variety of *Belemnites jaculum* is rather abundant and in good condition, sometimes showing its rarely-preserved phragmocone. The Ammonites occur chiefly near the base of the bed, and all that I have seen are small in size. The fine-ribbed variety of *Amm. speetonensis* reappears, and is accompanied by several allied forms, including *Amm. Astierianus*. When a collection of these small Ammonites is made, specimens are found with characters intermediate between the allied species; and I am inclined to think that the various forms of this closely-related group may be the result of the decadence and splitting up of the species *Amm. speetonensis* and its near neighbour *Amm. Astierianus*.

The Foraminifera, which are of large size and well preserved, occur curiously, being found cemented together in small hard pellets, not often larger than shot-corns.

But the most interesting palæontological feature of the bed is the abundance of the small Echinoderm. The tests of this group have been considered so rare in the series that we had Judd's authority for regarding a solitary specimen preserved in the Scarborough Museum as unique, though the occasional occurrence of beautiful detached spines of *Cidaris* of large size at various horizons showed that these animals were not unrepresented in the seas of the period. The identification* of my specimens as *Echinospatangus cordiformis*, Breyn., a highly characteristic Neocomian type, is important, and leads me to doubt the correctness of the *gisement* assigned to the Scarborough fossil, which Judd (who records it as *Toxaster complanatus*, Ag., one of the numerous synonyms of *Echinospatangus cordiformis*) supposes to have come from his "zone of *Amm. Astierianus*" (=*Bel. lateralis*-zone of my section). The specimen is in a somewhat different state of preservation from those I have found, as it is imbedded in a claystone nodule; but this nodule has the soft brown character of those occurring in this bed, and I think there is every probability that it came from this or a neighbouring horizon.

I have found a single example of the species in a pale bed about 20 feet higher in the section, in the zone of *Bel. semicanaliculatus* (fig. 6); but, with this exception, all I have yet obtained have come from the bed just described, *C 3* of fig. 5, and to this bed, therefore, I think the name of the fossil may well be applied.

* By Messrs. G. Sharman and E. T. Newton.

In the list given below, the fossils of the *Echinospatangus*-bed, so far as they have been determined, are separately indicated.

Top Beds of Jaculum-*zone.*—The remaining 9 or 10 feet of the *Bel. jaculum*-zone lying above the *Echinospatangus*-bed show alternations of dark and pale clays in thin bands, containing the characteristic Belemnite, along with *Vermicularia Sowerbyi* and other fossils. The upper limit of the zone is well defined by a thin double-bed of curiously mottled clay, the lower four inches being pale in colour with dark markings, while the upper five inches show pale markings on a dark ground, the two together forming an easily recognizable and conspicuous band. Above this horizon new species of *Belemnites* appear. The clays of this part of the series are well exposed in Black Cliff where the sea washes the base of the great landslip; and they are repeated in a similar position further south under the north slopes of the Speeton Beck Ridge, where they occupy a position so much higher than is indicated in adjoining beach-exposures, that a small fault throwing about 20 feet to the north probably crosses into the cliff between the two points (see ground-plan, fig. 1, p. 578). The mottled bands may also be traced high up on the ridge between Black and Middle Cliffs.

Fossils of the Zone of Belemnites jaculum, *Phil.*

	Lower beds.	Passage-bed, Compound Nodular Band. *D 1.*	Dark clay. *C11.*	*Noricus*-clays. *C 10, 9, 8.*	*Speetonensis*-clays. *7, 6.*	"*Pecten cinctus*-" and lower clays. *5, 4.*	*Echinospatangus*-bed. *3.*	Top Clays. *2, 1.*	Higher beds. *B.*
Belemnites jaculum, *Phil.*	...	*	*	*	*	*	*	*	*
—— ——, var. pistilliformis, *Blainv.*	...	...	...	*	*				
—— (resembling sulcatus, *Mill.*) (see Appendix, p. 612)...........	...	...	...	*	...	...	...	...	*
Ammonites noricus, *Schloth.*, and varieties	...	*	*	*					
—— speetonensis, *Y. & B.*, var. concinnus, *Phil.*	...	...	...	...	*				
—— ——, var. venustus, *Phil.* ...	...	...	...	...	6*	...	*		
—— Nisus?, *D' Orb.* (planus, *Phil.*)	...	...	...	?	*				
—— nucleus, *Phil.*	...	...	...	...	...	*	*	*	?
—— marginatus, *Phil*................	...	...	...	...	*	...	*	*	
—— rotula, *Sow.*	...	*	...	*	*				
—— angulicostatus ?, *D' Orb.*	...	...	...	*					
—— Astierianus, *D' Orb*.............	...	...	...	*	*	...	*		
—— hystrix ?, *Phil*...................	...	...	...	*					

List of Fossils (continued).

	Lower beds.	Passage-bed, Compound Nodular Band *D 1.*	Dark clay. *C11.*	*Noricus*-clays. *C 10, 9, 8.*	*Speetonensis*-clays. *7, 6.*	"*Pecten cinctus*-" and lower clays. *5, 4.*	*Echinospatangus*-bed. *3.*	Top Clays. *2, 1.*	Higher beds. *B.*
Ammonites sp.[1]	...	...	...	...	...	*	...	...	*
Crioceras (Ancyloceras ?) Duvalii, *Léveillé*	...	...	...	...	*	*	...	...	?
—— —— Puzosianum ?, *D'Orb.* (=C. ligatus, *Bean, MS.*)	...	...	...	*	*	*			
—— sp.[2]	...	*	*	*	*	*	...	*	*
—— sp.	...	...	...	...	7*	...			
Rostellaria Phillipsii, *Röm.*, = R. Parkinsoni, *Phil.*	...	...	...	?	*	*	*	*	*
—— sp.	...	...	...	...	...	...	*		
Cerithium aculeatum, *Forbes*	...	...	...	*	*				
Pleurotomaria, sp.[3]	...	...	...	...	...	*			
Trochus pulcherrimus, *Phil.*	...	...	...	8*	*	...	*		
Dentalium, sp.	...	...	...	...	*				
—— lævigatum, *Bean, MS.*	...	...	...	...	...	...	*		
Ostrea (? frons, *Park.*, *of Judd*)	...	...	...	...	...	*	...	...	*
——, sp.	...	*	*						
Exogyra sinuata, *Sow.*	*	*	...	*	...	*	...	*	*
†Pecten lens, *Sow.*, var. Morini, *De Lor.*	*	*	*						
—— cinctus, *Sow.*	?	*	...	?	...	*	?	?	
—— sp.	...	*	*						
—— sp.	...	...	...	...	*				
†Lima parallela, *Sow.*	...	...	*						
Plicatula, sp.	...	*	*						
Avicula, sp.[4]	...	*	*						
Inoceramus venustulus, *Bean, MS.*	...	...	...	*					
—— imbricatus, *Bean, MS.*[5]	...	...	...	*					
Nucula subangulata ?, *Forbes, MS.*	...	...	?	*	*	*	*	*	*
—— subrecurva, *Phil.*	...	...	...	...	?	?	*	*	*
†—— Vibrayeana, *D' Orb.*	...	...	...	...	...	...	*		
Leda scapha, *D' Orb.*	...	...	...	...	...	...	*		
Isocardia angulata, *Phil.*	...	...	...	*	*	*	*	*	*
Mya ? phaseolina, *Phil.*	...	...	...	*	*	...	*	*	*

[1] A species with coarse ribs at intervals, set with tubercles.

[2] The range of the undetermined specimens is here indicated; probably several species are represented.

[3] Fine large shells, but not well preserved.

[4] I have been informed by Prof. A. Pavlow that this unnamed species is known in Russia.

[5] This is probably only the adult form of *I. venustulus*, Bean.

† These species are recorded for the first time.

List of Fossils (continued).

	Lower beds.	Passage-bed, Compound Nodular Band. *D 1.*	Dark clay. *C 11.*	*Noricus*-clays. *C 10, 9, 8,*	*Speetonensis*-clays. *7, 6.*	"*Pecten cinctus*-" and lower clays. *5, 4.*	*Echinospatangus*-bed. *3.*	Top Clays. *2, 1.*	Higher beds. *B.*
Panopæa (? neocomiensis, *Desh.*, sp. *Judd*)	...	*	*	*	*	*	...	...	*
Thracia Phillipsii, *Röm.*	...	...	...	*	*	*	*	...	?
Pholadomya Martini, *Forbes*	...	...	...	*	...	...	...	...	*
Serpula articulata, *Sow.*	*	*	*	*	...	...	*		
—— antiquata, *Sow.*	...	?	...	...	...	...	*	...	*
Vermicularia Phillipsii, *Röm.*	...	...	...	...	...	*	*	*	*
Terebratula depressa, *Lam.*	...	*	*	*	...	?			
—— sella, *Sow.*	...	...	...	...	*	...	...	...	?
†—— Moutoniana, *D'Orb.*	...	...	...	...	*				
—— sp.	...	...	*						
Rhynchonella sulcata, *Park.*	...	?*	*	*	...	*	...	...	*
—— speetonensis, *Dav.*	...	...	...	*	...	?			
Terebratulina Martiniana, *D'Orb.*	...	...	...	...	...	*	...	*	
Pentacrinus annulatus, *Röm.*	...	*	*	*					
Echinospatangus cordiformis, *Breyn.*, = Toxaster complanatus, *Gmel.*	...	...	...	...	...	...	*	...	*
Cidaris (spine)	...	...	...	...	...	...	*	...	*
Trochocyathus conulus, *Phil.*	...	*	...	*					
Foraminifera	...	*	*	*	*	*	*	*	*
Meyeria ornata, *Phil.*	...	*	...	*	*	*	*		
Meyeria falcifera[1], *Phil.*, = Astacodes falcifer, *Bell*	...	...	...	*	...	...	*		
†Palinuridia scarburgensis, *Carter, MS.*	...	...	...	...	*	*	*		
Hoploparia prismatica, *M'Coy*	...	...	...	...	...	*	*		
——, sp. (chelæ)	...	...	...	...	...	...	*		
Fish &c. (vertebræ and teeth)	...	*	*	*	...	...	*		
Wood	*	*	*	*	*	*	*	...	*

B. *Zone of* Belemnites semicanaliculatus?

Immediately above the mottled bands, *C 1*, fresh forms of Belemnites appear, though the fauna does not otherwise immediately show much change, nor does *Bel. jaculum* become quite extinct, as I have met with small scattered examples 30 feet higher, and even above this there is a highly modified form which may be con-

[1] See Dr. James Carter's notes on this species in Appendix, p. 617.
† These species are recorded for the first time.

sidered a variety, though I think it deserves specific recognition (see Appendix, p. 611).

The Belemnites in these upper beds include several distinct forms, about the identification of which there is great uncertainty. Many of them have been referred to *Bel. semicanaliculatus*, but none are typical forms of that species, and Judd, who so named them, has since stated * that they are the *Bel. brunsvicensis*, Von Stromb. It is probable that some of these forms will be found to have restricted ranges, but this has not yet been demonstrated, and, in spite of the variety, these various types taken together form a well-marked group totally distinct from those of the lower beds. Being moreover by far the most plentiful fossils, they afford the readiest means of describing and identifying the upper portion of the section; and I therefore propose, pending more decisive determination, to apply provisionally to this part of the clay the older and better known name of the species, and to speak of it as the Zone of *Bel. semicanaliculatus*?

It is rare that opportunities for studying this zone in detail present themselves, and I can give no complete section, as my knowledge of it is still only partial. The beach south of Speeton Gap, where these beds mainly crop out, is very rarely stripped, and even when exposures do occur they are often encumbered by the large chalk boulders which here strew the beach, and which not only actually hide the beds, but have also been so pounded over them by the sea as to cause an obscure and battered surface. I did indeed, early in 1881, see a wide stretch of the beds to the southward of the Gap, but under conditions so unfavourable that I could do little more than note the direction of their strike, and that they consisted of banded clays with lines of large nodules; and when I went again in better weather to try to do more, the place was covered.

I still think, however, that with patience it may be possible some time to work out this part of the section also. Meanwhile I give a section (in fig. 6) of the beds at the base of the zone, from measurements at the foot of Black Cliff, in part corroborated by an exposure on the shore.

There is by no means the decisive change of fauna here that occurs at the base of the *Jaculum*-zone; but proceeding upwards we find many new species appearing, which shows, equally with the disappearance of many of the old forms, the changing character of the fauna, although there are examples of species overlapping in both directions at the junction.

The clays in this section are decidedly darker than in any mass of similar thickness below, but yet include, besides several narrower ones, one broad pale band with two layers of large nodules. The nodules throughout the entire zone are generally larger than those of the lower divisions, and are paler in colour, probably con-

* In a footnote to T. Davidson's "Notes on Continental Geology," Geol. Mag. (1869), vol. vi. p. 263.

taining a larger proportion of lime. They are occasionally, but not usually, fossiliferous.

The measurement of the beds in fig. 6 above the asterisk, having been made only in the great slip of Black Cliff, is somewhat doubtful. The clays seem to be in sequence, but I could not identify them in the Speeton Beck Ridge, where, however, the beds above a certain level are much disturbed and seem as though they may at some period have been forced forward bodily by an enormous foundering of the chalk, being for some distance nearly vertical, and then curving over in a large fold. In this fold on Speeton Beck Ridge the "Cement-beds," which Judd places at the base of his Upper Neocomian, are fairly well exposed, and the section given in fig. 7, which will serve to show their character, has been measured across them. If there be any interval between the bottom of this section and the top of the last, I do not think it can exceed from 20 to 30 feet.

Judd, enjoying, no doubt, exceptional facilities during the working of the seam, gives a long list of fossils from these "Cement-beds," and correlates them with the Lower Greensand and Atherfield Clay of the south of England. He moreover maps these beds and the beds above them in the great slip of Black Cliff, and states that they may be well studied there. But the pale clay with nodules which is now prominent in this part of the section (the *Echinospatangus*-bed) belongs, as I have shown, to a much lower horizon, nor is it likely that there has been any radical change here during the last twenty years. There is indeed a much higher band of large pale fossiliferous septaria in dark clay (shown in fig. 6) occasionally slightly exposed near the southern end of the slip, which may possibly represent the "Cement-beds," but of this I am doubtful. If any of the fossils of the above-mentioned list were collected from the slip, there has almost certainly been a mingling of the faunas of two distinct horizons. For this reason I suspect the authenticity in the "Cement-bed" list of *Amm. marginatus*, *A. rotula*, *A. Nisus*, *Trochus pulcherrimus*, *Inoceramus venustulus*, and a few other species.

South of Speeton Gap, beds of dark clay and banded clay with nodules may be observed between the slips of chalk, and similar beds are occasionally visible in limited exposures on the foreshore as far as the broken ground extends. These clays, which show here and there brilliant pyrites in groups of fine cubical crystals, contain the same species of *Belemnites* as the cement-beds, and seem to have in general the same fauna.

There is a remarkable scarcity of Ammonites throughout the zone.

In the following list are recorded the species obtained by me from the zone of *Bel. semicanaliculatus* ?. Pending the completion of the section, I have not attempted to indicate the vertical distribution.

Fossils of the Zone of Belemnites semicanaliculatus ? *.

Belemnites semicanaliculatus ? = Bel. brunsvicensis, *Stromb.* (see Appendix, p. 611).
—— (resembling sulcatus).
—— jaculum, *Phil.*
——, sp. (extreme form of *jaculum* ?).
——, sp. (resembling *lateralis*, but a distinct species).
Ammonites Deshayesii, *Leym.*
—— nucleus ?, *Phil.*
Crioceras, sp.
Ancyloceras, sp.
Hamites, sp.
Nautilus, sp.
Rostellaria Phillipsii, *Röm.* = R. Parkinsoni, *Phil.*
†—— candidula, *Forbes, MS.*
—— (bicarinata, *Leym., of Judd*).
Pleurotomaria, sp.
Turbo, sp.
Dentalium (ellipticum ?, *Sow., of Judd*).
Ostrea, sp.
Exogyra (sinuata, *Sow., of Judd*).
Pecten orbicularis, *Sow.*
Lima (spec. nov., *Judd*).
†Pinna tetragona, *Sow.* (?=gracilis, *Phillips*).
Cucullæa securis, *Leym.*
Nucula (very similar to Menkei, *Röm.*, of the Kimeridge).
—— subangulata, *Forbes, MS.*
†—— impressa, *Sow.*
Mya ? phaseolina, *Phil.*
Isocardia angulata, *Phil.*
Astarte lævis, *Phil.*
Panopæa neocomiensis, *Leym.*
Pholadomya Martini, *Forbes.*
†Serpula plexus ?, *Sow.*
—— antiquata, *Sow.*
Vermicularia Sowerbyi, *Phil.*
†Terebratula Seeleyi, *Walk.*
Rhynchonella sulcata, *Park.*
Echinospatangus cordiformis, *Breyn.*‡
Cidaris (spines).
Fish. Wood. Foraminifera.

A. *The Uppermost Beds of the Speeton Clay* : *Zone of* Belemnites minimus, *List.*

There is no section at Speeton showing the point of emergence of the clays from beneath the Chalk, for as soon as the base of the chalk is lifted above the shore-line it hides everything below by its continual slipping.

I believe it is usually taken for granted that the remarkable unconformity seen below the Red Chalk along the western edge of the Wolds extends to Speeton, and marks the junction of the Red Chalk there with the underlying beds. The Rev. T. Wiltshire, however, has described the Red Chalk as passing into the Speeton Clay §; and at a later date, C. J. A. Meyer published a brief note on a section at Speeton in which this passage was very distinctly seen ||, but his note, perhaps from lack of full information concerning the position of the section in these slipped cliffs, does not seem to have had much effect in altering the prevalent view. There can be no doubt, however, that we have at Speeton below the Red Chalk beds of marly shale and clay, which, while they present many of the

* Several species will be found recorded in this list which occur in the Lower Gault, showing the gradually changing character of the fauna. The list is admittedly very incomplete, partly owing to the rarity of good opportunities for collecting from these beds, and partly to the difficulty of obtaining specific determinations of the fossils collected.

† These species are recorded for the first time. Specific names in brackets indicate that the determination of a previous author has been used, but not confirmed.

‡ One specimen only, from the lowest beds, see p. 596.

§ Wright's Mon. Brit. Foss. Cret. Echin. (Pal. Soc.), p. 9, 1862.

|| Geological Magazine, vol. vi. (1869), p. 13.

physical characteristics of the Speeton Clay, contain a fauna very closely allied to that of the Red Chalk; and that these beds are far too thick to be explained * as the result of a "working up" of the underlying clays into the base of the Red Chalk.

Fragments of these beds may occasionally be found among the slipped ground under the chalk escarpment; and recently the sea, having effected a considerable removal of chalk-débris in the cliff-foot south of the Gap, has revealed in three different places large masses of the beds. These, though not actually in place, have slipped in such masses as to show very well the character and fossils of the deposits, and also to some extent their sequence.

The first of these slips is at present † to be seen at the cliff-foot about 200 yards from Speeton Beck. At this place the beds are much shattered, having probably slipped for some distance; but it is still easy to trace several distinct beds and to collect a fauna rather numerous individually, though not specifically. The beds consist of brown, grey, dull red, and brilliantly variegated marly clay and shale.

A short distance further south there is another similar, though smaller, exposure; and beyond this, about 350 yards from Speeton Gap, the most extensive and important of the disclosures has been made. At this place the beds may be traced for fully 20 yards along the cliff-foot, rising in one place a few feet above high-water mark, and though they are undoubtedly slipped, they are probably not so very far from their original position, as the base of the Red Chalk cannot here lie much above sea-level. The sequence of the beds is well preserved, and they are clearly in the order of their deposition. They rest on black clay in which fossils are very rare—the only recognizable fossil I have found being a fragment of *Bel. semicanaliculatus*?—and seem to do so naturally, and not by reason of the slipping; but the state of the section prevents one speaking positively on this point. The section observed is shown in fig. 8.

In this section the green and yellow gritty bed with nodules forms a very striking and distinct horizon, and might be thought to mark a break in the series. It exhibits many peculiar features, being full of nodules that look as though they might be derivatives, and frequently present a curiously pitted and partially decomposed surface, as if through erosion. These are often coated thickly with gritty green matter (probably glauconite), and sometimes form a centre from which springs a mass of radiating crystals (selenite) which completely surrounds the nodule in a layer from an inch to three inches thick. But the variegated marly clays extend below this nodular bed, and do so regularly, without any appearance of erosion or unconformity; and though, as I have said, one could not say positively that there is an actual passage from them to the black clay with *Bel. semicanaliculatus*? on which they rest, the evidence is all in favour of their doing so. Both beds contain similar small brown-coated "potato-nodules," and otherwise "fraternize" in character, as one might say.

Somewhat analogous is the evidence above this gritty and nodular

* W. Hill, Quart. Journ. Geol. Soc. vol. xliv. p. 338. † January 1889.

band for a passage of the clays into the true Red Chalk. The crushed Red Chalk resting on the clayey beds in this exposure may not be in place, and, indeed, in this case probably is not; but the dull red band two feet below it might really be described as a clayey red chalk, and is evidently of the nature of a passage-bed. The presence above this chalky clay of at least two feet of the dark mottled shales with glauconite, which bear far more resemblance to the Neocomian clays than they do to the Red Chalk, shows unmistakably that there were alternating conditions before the Red Chalk proper began to form. The state of preservation of the fossils, though perhaps not of much consequence, deserves mention as evidence in the same direction. In some of the layers the fossils are preserved in a semicrystalline condition, as in the Red Chalk; while in others interstratified with them the shell-substance remains as a white opaque impression in the clays, as is usual in the Neocomian Clays below.

In these marls there seems to be much extraneous gritty matter, and all are streaked and dappled with glauconite. In the dull red band small smooth pebbles (lydites) not larger than duck-shot have been observed *.

The fauna of the Speeton marly beds is limited, but very interesting, and we may hope that future exposures will enable us to lengthen the list. During 1886 and 1887 I saw several small exposures of marly clays with green streaks among the rocks on the beach to the eastward of these slips, close under the chalk escarpment, and, though I had not then learned to recognize them, these were probably the same beds, in place, as those just described. The furthest eastward of these was at half-tide nearly opposite to Nanny Goat's House; but as this exposure was in a waterpool it was difficult to examine. Fossiliferous Upper Neocomian beds, with *B. semicanaliculatus* ?, *Rostellaria Phillipsii*, *Cucullæa securis*, &c., have occasionally been poorly exposed within a short distance of these marly beds, striking in the same direction.

The following species have been identified in my collection from the marls :—

Belemnites minimus, *List.*	Ostrea, sp.
—— attenuatus, *Sow.*	Avicula Rauliniana ?, *D'Orb.*
—— ultimus, *D'Orb.*	Nucula pectinata ?, *Sow.*
Inoceramus concentricus, *Park.*	Lingula, sp.
—— sulcatus, var. ?, *Park.*	Vermicularia elongata, *Bean, MS.*†
——, sp. (a larger form).	Fish (scales).

This list, though limited, shows clearly the affinity of the beds to the Red Chalk, and those species, such as *Bel. attenuatus*, *Inoceramus concentricus*, &c., which are not found in the Red Chalk at Speeton are still forms well known in the Gault, which is agreed to be, in part at any rate, a synchronous formation.

The possibility of a representative of the Gault other than the

* In colour and some other characteristics, as also in stratigraphical position, these marls seem somewhat to resemble the "Flammen-Mergel" of Germany.

† Figured in Rev. T. Wiltshire's 'Red Chalk,' pl. iii. figs. 1, 1*a*.

Red Chalk existing at the top of the Speeton Clay has been once or twice suggested, but has been regarded as untenable. In these beds, however, we have probably a representative of the Lower Gault, while the Red Chalk itself may represent the Upper division of the Gault.

With these beds I conclude my description of the Speeton Clay; and if I have entered at great detail into the discussion of the various horizons, it is because I know by experience how difficult it would be for a student unacquainted with the locality, needing these details, to acquire them.

Summary.

In these descriptions the points to which I would especially draw attention may be summed up as follows:—

1. The sandy blue shales now seen in the cliff near Filey are not in place, but are "bouldered" in drift; and most, if not all of them, are of Liassic age.

2. The bituminous shales (Upper Kimeridge) extend upwards to the "Coprolite-bed" without the intervention of the beds described as "Portlandian."

3. There is no unconformity traceable at the horizon of the Coprolite-bed.

4. It is in the "Zone of *Belemnites lateralis*," as defined in this paper (= the "*Astierianus*-zone of the Lower Neocomian" of Judd), that we find the "Portlandian beds" of Leckenby, this zone having marked Jurassic affinities.

5. A very well-marked band of nodules with scattered coprolites caps the "Zone of *Bel. lateralis*," and this band constituted the "Coprolite-bed" of Leckenby, though not of Judd.

6. The thickness of clay between the bituminous shales and the Red Chalk is probably really under 300 feet.

7. The distribution which has been assigned to some of the characteristic fossils of the clays needs revision and alteration; among the species thus affected are:—*Ammonites Astierianus*, *Amm. rotula*, *Amm. speetonensis*, *Amm. Gravesianus*, *Toxaster complanatus*, *Trochus pulcherrimus*, *Inoceramus venustulus*, and others.

8. The term "Middle Neocomian," as hitherto defined in the Speeton section, is unnecessary and misleading, since the beds which have received this name have a "Lower Neocomian" fauna above as well as below them, and do not seem in themselves to contain any peculiar or distinctive types.

9. As stated by Meyer, marly shales exist between the Red Chalk and the Speeton Clays, strongly suggestive of a passage from one to the other.

10. The section may be very conveniently divided into life-zones by its Belemnites.

Conclusion.

In working on my subject certain inferences have presented themselves, which I append, as it may be that among them are sug-

gestions which may bear fruit. But as the direct object of my work has been to describe the facts of the Speeton section and not to make explanations of them, I have not sought to elaborate this part of my paper.

My study of the Speeton series has led me to believe that in this area there has been an almost unbroken period of gradual deposition, proceeding at all times slowly, and occasionally all but ceasing, but nevertheless continuing from the Upper Jurassic stage not only throughout the Lower Cretaceous *, but possibly throughout the Upper Cretaceous also.

To support the latter part of this view, the great unconformity below the Red Chalk in the inland sections along the western edge of the Wolds needs explanation. But I see no difficulty in supposing that during the deposition of the clays in the Speeton area there was a slow elevation going on in the sea-bottom at some distance to the westward and south-westward; and that this movement, without materially altering the condition of affairs at Speeton, resulted in the appearance in the south-west of a ridge of low land, which eventually divided the once continuous seas of East Yorkshire and Lincolnshire.

Rapid denudation of this ridge, as its mudbanks of Kimeridge Clay emerged, may have furnished, among other material, the fragments of black phosphatic stone which occur at Speeton, lying, as I have shown, not only in particular bands, but also scattered, somewhat sparsely and irregularly, throughout the greater part of the clays. These fragments, many of which could scarcely have been carried by currents, may, I think, have been conveyed from the shore-line by the agency of some drifting body, such as the broad-fronded sea-weeds, which may have buoyed them up and dropped them on a quiet muddy bottom as it floated across.

The elevation and denudation of this ridge may have commenced about the close of the Jurassic period; and it went on throughout the Lower Cretaceous, by which time the crest of the ridge had been planed down to the level of the Lower Lias. During all this time the Speeton area seems never once to have emerged, but the proximity of timbered land is shown by the abundance of wood preserved at various horizons in the clays.

But at the close of the Lower Cretaceous the movement in the west seems to have been reversed; elevation ceased, and gave place to a gradual sinking of the whole area, during which, as the waves once more passed over the ridge, the conglomeratic bed at the base of the Red Chalk of the western Wolds was formed, and thus this rests upon the edges of the Jurassic strata on the anticline with a strongly marked unconformity, though, could we trace the horizon continuously to Speeton, I suspect we should find that in going eastward the unconformity would give place to overlap, and that we should finally run into the marly shales below the Red Chalk in the uninterrupted succession of the Speeton section.

* Professor Phillips seems to have been of this opinion (Geol. of Yorksh. 3rd ed. pt. i. (p. 100).

We can easily trace in the Red Chalk itself the effect of the deepening waters, at Speeton as elsewhere, as Hill's * recent researches so admirably show, and in the same bed we find clear proof of the greater comparative depth of the sea at Speeton than further west. Gradually, however, as the land sank, the effect of this difference of level became less apparent, until a wide ocean without local conditions spread once more over the Eastern Counties, and deposited a winding-sheet of chalk indiscriminately over everything.

Thus the Speeton clays seem to have been deposited not far from the western edge of an ocean which probably stretched eastward, as Judd † has suggested, over the northern part of Central Europe.

Could we see, then, a continuous section east and west across the Wolds, I should expect to find a westward thinning of the deposits as a whole, culminating probably in the complete disappearance, first of the upper beds, and finally of the lower beds also, for in approaching the elevated area such portions of the series as were deposited there before the elevation reached its maximum would afterwards be partially or wholly removed. The clays of Speeton might also be expected to give place to beds of rougher material as they approached the western coast-line.

It is much to be regretted that we can now obtain no direct information regarding the actual conditions in the western area, the inland pits mentioned by Judd having long been closed and overgrown.

As proof of the extended period covered by the clays, and as favouring the view of a gradual passage into the Upper Cretaceous, it is important to note the occurrence, especially in the upper portion of the Speeton section, of several species known in the Gault, and these are nearly all species which are either confined to the Lower Gault or range through both divisions.

Thus, if I read the Speeton section aright, we have, in the lower portion, in the clays of the zone of *Bel. lateralis*, beds which mark the passage from Jurassic to Lower Cretaceous or Neocomian; and in the upper part, in the marls below the Red Chalk, a similar passage into the Upper Cretaceous, and an unbroken sequence between. And if this be so, then these clays must necessarily bridge over the period of the formation of the Portlandian, Purbeck, and Wealden beds, as well as of the Lower Greensand, in the south of England. It is not, however, in these southern beds, where the marine history of the Jurassic period has been abruptly cut short, and the opening chapters of the Cretaceous replaced by a story of freshwater and estuarine conditions, that we ought to look for the equivalents and analogues of the Speeton beds; but rather in those localities, whether at home or abroad, where that history has been given complete and in a similar manner. Nor, as it seems to me, should we be bound to adopt as the exact limits of a period the lines drawn where the conditions have been local and incomplete, but rather strive to define them more exactly in an area of better development.

* Quart. Journ. Geol. Soc. vol. xliv. p. 320.

† *Ibid.* vol. xxvi. p. 346.

Many very interesting questions arise with regard to the correlation of the divisions as now proposed in the Speeton beds with the beds of similar age in Lincolnshire and abroad, but with these it is not for me to deal.

In conclusion, I beg to render my hearty thanks to Messrs. G. Sharman and E. T. Newton, to Mr. T. Roberts, to Dr. James Carter, and to Mr. J. F. Walker, for their invaluable assistance in determining the fossils, to Mr. C. Fox-Strangways for his advice and aid in many ways, and to Mr. W. B. Headley for the loan of specimens and for his freely-rendered help in collecting.

Note, July 1, 1889.—Since this paper was read, I have received copies of two important contributions to the literature of the subject*, of which the authors are two eminent Russian geologists who visited Speeton last autumn during the excursion arranged for the Geological Congress. I had the pleasure of there meeting these gentlemen, Professor A. Pavlow, of the Moscow University, and M. Serge Nikitin, of the Geological Survey of Russia; and it is partly their expressed desire for further information regarding the section that has led me to publish the observations printed above.

In these papers the Upper Jurassic and Lower Cretaceous beds of Russia and England are compared, and results of great importance are arrived at.

Both authors agree that the Speeton section affords the best basis for this comparison, and find in it the equivalents of Russian beds which had hitherto been supposed to be unrepresented in Western Europe.

They see in the 'Zone of *Belemnites lateralis*' (which fossil is declared to be synonymous with *Bel. corpulentus*, Nikitin) the equivalent of the 'Upper Volga beds' of Russia. They likewise show a remarkable parallelism in the higher portions of the section, recognizing in the varieties of our *Ammonites speetonensis* species well known in Russia (see Appendix, p. 613).

M. Nikitin indicates that our '*Noricus*-beds' are also represented in the Simbirsk section, but herein Prof. Pavlow differs from him. The latter author believes that these beds are wanting in that section, and that the gap which they leave represents a break between the Jurassic and Cretaceous portions of the series; thus he relegates the whole of the "Volga beds" (and with them their equivalents in the Speeton section, including the *Lateralis*-zone) to the Jurassic. M. Nikitin, however, if I understand his meaning aright, would place the "Volga beds" so as to correlate the upper portion with the Lower Cretaceous and the lower with the Upper Jurassic.

* M. Serge Nikitin. 'Quelques Excursions dans les Musées et dans les terrains Mésozoïques de l'Europe occidentale, et comparaison de leur faune avec celle de la Russie.' Printed first in Russian at St. Petersburg towards the close of last year, but now fortunately rendered more generally available by a French translation printed in the 'Bulletin de la Société Belge de Géologie,' tome iii. (April 1889), pp. 29–58.

Prof. A. Pavlow. 'Etudes,' &c. Pt. I. "Jurassique supérieur et Crétacé inférieur de la Russie et de l'Angleterre." Avec 3 planches. Moscou, 1889. (Printed in French.)

Professor Pavlow also gives a diagrammatic view of the equivalents of the "Volga beds" in Lincolnshire and the South of England, correlating the Purbeck beds of Swindon and the Portland stone, and also the Spilsby Sands, with the "Upper Volga beds," and therefore with the zone of *Bel. lateralis* at Speeton. M. Nikitin also sees in the Purbeck beds of Swindon the freshwater equivalents of part of the "Upper Volga," and therefore of the zone of *Bel. lateralis*.

I need scarcely point out that this correlation of the *Lateralis*-zone with the uppermost beds of the Jurassic of the South of England, made before it was known that this zone constituted the 'Portlandian beds' of Leckenby, agrees well with the results independently arrived at in my paper.

Both authors agree in recognizing in the bituminous shales of Speeton (Upper Kimeridge) the equivalents of the "Lower Volga beds" of Russia; and they seem to desire to apply the term "Lower Portlandian" or "Bolonian" to these beds, and to beds of similar age elsewhere in England, thus considerably restricting the use of "Kimeridgian" in the Speeton section.

The importance of these memoirs is apparent, and they are almost certain to lead to further discussion.

The papers contain, besides, many palæontological observations of great value, in which the fossils from the two countries are compared. In a few instances I shall be able to call attention to the results of this part of their work in the Appendix to this paper.

APPENDIX.

Notes on some of the Fossils.

The palæontology of the Speeton Clay is by no means in a satisfactory condition, as not only are there many important forms which have not yet been identified or described, but also of those which have been named we have frequently only figures of doubtful merit without accompanying descriptions.

In this paper I have not attempted to compile a full list of the known species of the deposit, but have given only those which have been identified from my own collection. My lists, therefore, should be taken as illustrations of the fauna rather than as full catalogues. A much fuller list is contained in Professor Judd's paper; and several other species not mentioned therein may be found in the tables of fossils in Phillips's 'Geology of Yorkshire,' 3rd ed. When the task of thoroughly working up the fauna shall have been undertaken by a palæontologist conversant with the foreign equivalents of the deposit, a rich harvest of new forms and of forms new to this island will almost certainly be gathered.

The following notes on the range and affinities of some of the commoner species may be found useful as a guide in collecting, or for comparison with other localities.

Belemnites Owenii, Pratt, and varieties.

The specimens of Belemnites, few in number, found in the shales (F) below the "Coprolite-bed" have all been referred to this species, but they represent an extreme range of variation. One specimen only approaches the normal form of the species, while the majority belong to a long and slender variety, often deeply channelled throughout a great part of its length, which, were it thought advisable to break up the species, might be considered a separate form. This variety comes near to *Bel. spicularis*, Phillips, from the Kimeridge Clay of Cromarty, as figured in 'Brit. Bel.' pl. xxxviii. f. 82 (1870, p. 122). Phillips, in his 'Geology of Yorkshire,' 3rd ed. (pl. xxv. f. 9) has also figured an imperfect specimen of this variety under the name of *Bel. Juddii*; he gives no description, but in a short note refers to it as "a long Belemnite from Speeton in the possession of Mr. Lee. . . . It agrees nearly with a species found in the Kimmeridge Clay near Oxford." If, therefore, it should hereafter be thought necessary to grant this form specific recognition, Phillips's name should have preference. Professor A. Pavlow, who has examined my collection, seems to recognize among these forms the *Bel. magnificus*, D'Orb., a near ally of *Bel. absolutus*, Fisch.*

Belemnites lateralis, Phil.

This abundant species shows a considerable range of variability. The commonest form is short and very stout, but another variety attains a greater length in proportion to its breadth. The shortness of the former variety is often accentuated by the decayed and deeply eroded condition of many of the guards, which tends to reduce the length considerably †. I have not noticed any difference in the distribution of these varieties.

Reference has already been made to the doubtful form in the Coprolite-bed, which may possibly be only a variety of this species; and also to the species resembling *Bel. lateralis* which occurs in the zone of *Bel. semicanaliculatus*?.

This latter form Phillips seems to have included with *B. lateralis*, and may, I think, have figured it in the inner outline of that species (in 'Geol. of Yorks.' 3rd ed. pl. xxv. f. 8). Respecting it he notes (p. 334) that it "corresponds to what has been called *B. semisulcatus* etc. of Brongniart." But the difference between the adults of the species in the upper zone, which are never large, and the massive guards of *Bel. lateralis* is very striking in every way; and even when specimens of the same size are compared, it is easy to see the distinction at once, for while *Bel. lateralis* shows a gradual thickening from apex to base, the former species attains its greatest thickness about halfway down the guard and shows a well-marked constriction towards the phragmocone. I think these two forms,

* A. Pavlow, 'Etudes,' &c. (*sup. cit.*) p. 42.

† M. Nikitin recognizes in these varieties (1) *Belemnites corpulentus*, Nik., and (2) *Bel. russiensis*, d'Orb., which occur in the "Upper Volga beds" of Russia. (Quelques Excursions, &c. p. 40.)

separated as they are by more than 120 feet of clay in which neither occurs, are undoubtedly specifically distinct.

I have not found any Belemnite within the range of *Bel. lateralis* which could not be referred to that species; nor have I found any undoubted specimen of the species above the Compound Nodular Band.

BELEMNITES JACULUM, Phil.

This very well-marked "hastate" form, which occurs in great profusion at Speeton, though it varies in shape between the slender graceful outline of *Bel. subfusiformis*, Raspail, and the extremely obtuse form of *Bel. pistilliformis*, Blainville, maintains throughout its zone its easily recognizable specific characters.

The variety *pistilliformis* is most abundant towards the base of the *Speetonensis*-beds, and does not seem to range much higher. The slender form, on the other hand, ranges throughout the zone. Specimens in which the phragmocone is preserved are rare.

This species does not die out in the abrupt manner of *Bel. lateralis*, but lingers on in a few dwarfed specimens into beds some distance above the limits assigned to it in my section. There is also (as mentioned at p. 600) a form present in the zone of *Bel. semicanaliculatus*? which has been supposed to be an extreme variety of this species; but it is so very distinct from the normal type that I think it deserves to rank as a separate species, especially as it does not occur along with the true form.

One variety of the species is recognized by the Russian geologists as corresponding to their Neocomian form *Belemnites Jasikowi*, Lahus *.

BELEMNITES SEMICANALICULATUS?

I have already mentioned in an earlier page the numerous forms of the genus which occur in the upper part of the Speeton section, and the difficulties connected with them. They have not yet been worked up, and when this is done I think that at least three types, and probably more, will be recognized, either as species or as very distinct varieties. By far the commonest form is the one which was first doubtfully assigned by Judd to *Bel. semicanaliculatus* (non Blainville) †, and afterwards to *Bel. brunsvicensis*, Strombeck ‡. I have felt the inconvenience of denoting a zonal division by the name of a doubtful species, but cannot see how to avoid doing so, as I have not been able to find any other plentiful fossil characteristic of the whole division. I have therefore applied the term provisionally. In the lower part of the zone this species is represented by a rather long and slender variety which generally shows a highly polished surface; but towards the top of the division this is replaced by a shorter and proportionately thicker form. Neither variety is grooved; but a deeply grooved species is occa-

* A. Pavlow, *sup. cit.* p. 41, and pl. iii; and S. Nikitin, *sup. cit.* p. 42.
† *Op. cit.* p. 245.
‡ In a note to a paper by T. Davidson in Geol. Mag. vol. vi. p. 263.

sionally found in the same zone which closely resembles the species known in the Oolites as *Bel. sulcatus*, and a solitary example of the same form has been noted in the zone of *Bel. jaculum* (see p. 592).

Belemnites minimus, List.; B. attenuatus, Sow.

I have not found these Belemnites lower in the section than the marls immediately below the Red Chalk. As Phillips includes them in his list of Speeton-Clay fossils, and as specimens occur in most of the old collections, it would appear that the uppermost "passage-beds" in which these occur have long been known, though the distinction between them and the underlying clays has not always been recognized.

Ammonites.

Individually this genus is not nearly so abundantly represented in the Speeton Clay as *Belemnites*, though the number of species is much greater. They become rarer as we ascend in the section, and are very scarce in the zone of *Bel. semicanaliculatus*?

Ammonites Gravesianus, D'Orb.; A. Irius, D'Orb.

This species or group of species (*Am. quadrifidus*, Bean, MS., and *Am. cavaticus*, Bean, MS., of the old collectors) occurs only, so far as I know, in the zone of *Bel. lateralis*. They are considered as Portlandian forms, but it has been stated in a recent paper that their determination is uncertain. M. Serge Nikitin, the author of the paper in question, has very kindly furnished me with the following translation of the passage in his work ('Quelques Excursions en Europe occidentale,' par S. Nikitin: St. Petersburg, 1889; published in Russian) in which he refers to them:—"En étudiant les musées de York et de Scarborough je n'ai pas réussi d'y voir les Ammonites citées par Judd; au contraire, tout ce qui est décrit et déterminé dans ces musées sous les noms d'*Ammonites Gravesianus*, *Amm. gigas*, et en partie *Amm. triplicatus* sont les formes épaisses d'*Olcostephani* du groupe *Bidichotomi* décrits par MM. Neumayr et Uhlig ('Palæontographica,' xxvii.) des dépôts néocomiens du Hils allemand, comme par ex. *Olc. Keyserlingi*, *marginatus*, *multiplicatus*, etc. Je suppose que ces formes tirent leur origine, comme nous le verrons ensuite, d'un des horizons supérieurs de l'argile de Speeton, mais pas de dessous de la couche à Coprolithes"*.

Since, however, I have now shown that these forms occur in that portion of the Speeton section which the Russian geologists concur in synchronizing with their "Upper Volga beds," we may take it that their age is satisfactorily established.

By far the finest collection of these Ammonites extant is that made by Leckenby, now in the Woodwardian Museum at Cambridge.

* Since my paper was read the full text of M. Nikitin's valuable paper has become available through the French translation, to which reference has already been given. The above passage will be found at p. 39 of that work.

Ammonites noricus, Schloth.,=A. neocomiensis, D'Orb.

This is decidedly the most abundant of the Speeton Ammonites, but appears to be strictly confined within the limits of its zone (beds *C 8* to *D 1* of sections). It shows several distinct varieties, which received specific recognition from the early collectors, and probably also from many foreign palæontologists; but, as noted by Judd, a moderate collection will show that these pass insensibly into one another. Leckenby records an allied form, *A. evalidus*, Bean, from beds low down in the bituminous shales (Upper Kimeridge) (see diagram fig. 2), which Judd states (Q. J. G. S. xxiv. p. 246) to be *Amm. consobrinus*, D'Orb.; but in a later paper, referring to the same species as found at Knapton, Judd places it under *Amm. fascicularis*, D'Orb., a different shell (Q. J. G. S. vol. xxvi. p. 328), thus illustrating the uncertainty which surrounds these species.

There is, however, one very distinct, though allied species, possibly the *Amm. hystrix*, Phil., in which the costæ develop tubercles and spines; but it is a shell of rare occurrence.

Ammonites speetonensis, Young and Bird; var. concinnus, Phil., and var. venustus, Phil.

The variability of this species is so great that it is difficult to mark out its limits. On the one hand, the coarse-ribbed variety (*concinnus*, Phil.) approaches so closely to the Upper Jurassic species *Amm. biplex*, Sow., that it has sometimes been wrongly identified as belonging to that species: and, on the other hand, the fine-lined form (*venustus*, Phil.) merges almost insensibly, especially in young specimens, into *Amm. Astierianus*, D'Orb.; and between these two extremes there is every gradation. The shell is not abundant except in the "main *Speetonensis*-bed" (*C 6*), but it undoubtedly occurs in the "*Echinospatangus*-bed" (*C 3*), and probably ranges quite to the top of the zone of *Bel. jaculum*. I know of no really satisfactory figures of this species or of its varieties *; it is a form which stands in great need of elucidation.

Ammonites Astierianus, D'Orb.

Touching *Amm. speetonenis*, var. *venustus*, on the one hand, this species on the other approaches closely to *Amm. marginatus*, Phil., the line of demarcation between the three in a large collection being difficult to draw, although the extreme forms are very distinct.

The species is not very easy to localize in the section, as it is nowhere plentiful. It certainly occurs in the "*Noricus*-beds," but not, I think, lower; and ranges upwards as high as the "*Echinospatangus*-bed," though I have not yet detected it at some of the intermediate horizons. Its distribution may, perhaps, be said to coincide roughly with that of *Bel. jaculum*. I have not found any undoubted specimens of it within the zone of *Bel. lateralis*, the nearest approach to it being the small fine-lined Ammonite which

* Written before the appearance of Prof. Pavlow's paper, in which young specimens of this species are figured. He recognizes in them *Olcostephanus fasciatofalcatus*, Lah., and *Olc. subinversus*, Pavl.

occurs plentifully in the "*Astarte*-beds" of that zone; but these have been identified by Professor Pavlow as probably *Olcostephanus subditus*, Traut., a shell well known in the "Upper Volga" of Russia.

Ammonites marginatus, Phil.

In the extreme forms of this small species the tubercles around the umbilicus develop into short spines, and it is then very distinct from any of its allies; but, as noted above, the less pronounced varieties can scarcely be distinguished from the young of certain varieties of *Amm. Astierianus*. It seems to be confined to the upper part of the zone of *Bel. jaculum*, occurring most frequently in the lower part of the *Echinospatangus*-bed, though nowhere abundant.

Ammonites nucleus, Phil.

This small and obscure species is rather abundant in the upper part of the zone of *Bel. jaculum*, and I have found specimens which may belong to it as high as the "Cement-beds." Judd has pointed out the relationship of this species to *Amm. marginatus*; and there is another undescribed form or variety in the same beds which also comes within the group.

If, as I think, the area has undergone very few physical changes during a long period, we may expect to find many slowly-changing species with limits difficult to define.

Ammonites rotula, Sow.*

This is a well-marked species, very distinct from any of those above-named, and apparently with no allies in the clays. It is nowhere plentiful; I have a single small specimen from the Compound Nodular Band (*D 1*) and others from the *Noricus*-beds (*C 8* and *9*), but it is in the "main *Speetonensis*-bed" (*C 6*) that it is easiest to find. I have not traced it higher.

Ammonites Nisus, D'Orb. (Judd); Amm. planus, Mant. (Phillips).

This shell occurs about midway in the zone of *Bel. jaculum*, but it is very rare. D'Orbigny's figure and description of *Amm. Nisus* indicate a smooth shell, but the Speeton specimens are marked with faint striæ.

Crioceras or Ancyloceras.

This group is very well represented at Speeton, but it is not often that the specimens are well preserved. Several very distinct species occur, five being named in Judd's list, besides three or four others recognized as distinct, but not identified.

That author seems to consider that the whole probably belong to the genus *Ancyloceras*. I have unfortunately not yet learned to distinguish these species well, and can give but little information as to their distribution. The lowest level to which I have traced the genus is the Compound Nodular Band, where very large specimens

* Recognized by Prof. A. Pavlow as probably = *Olcostephanus kaschpuricus*, Traut

become suddenly plentiful; and from this horizon the genus ranges upwards, varying from time to time in form and abundance, to the upper part of the zone of *Bel. semicanaliculatus*? The species in the higher part of the clay, above the "Cement-beds," are certainly different from those at lower horizons. A form which I think is *Crioceras Puzosianum*, D'Orb., is particularly abundant between the *Noricus*- and *Speetonensis*-beds.

TROCHUS PULCHERRIMUS, Phil., and CERITHIUM ACULEATUM, Forbes, MS.

These delicate and beautiful shells abound in the upper *Noricus*-beds, and pass upwards into the "main *Speetonensis*-bed," and the first-mentioned persists in a dwarfed variety as high as the *Echinospatangus*-bed, but I have not found them elsewhere in the section.

EXOGYRA SINUATA, Sow.

This is one of the commonest fossils of the Speeton Clay; but though a strong shell it is generally much crushed, and is difficult to obtain even in fair condition. Judd notes several distinct subspecies or varieties occurring at different horizons. I have found the shell as low as the "*Lingula*-bed" of the zone of *Bel. lateralis* (*D 5*), and upwards as high as the clays just below the "Cement-beds."

PECTEN LENS, Sow., var. MORINI, De Lor.

The shell referred to this species occurs in the "*Astarte*-bed" of the *Lateralis*-zone, and is plentiful in the neighbourhood of the Compound Nodular Band, and particularly in a shelly layer about a foot above that stratum. It is said not to be separable from the Jurassic species.

AVICULA INÆQUIVALVIS, Sow.

Another Jurassic species of wide range, to which has been referred a shell which occurs rather abundantly in the Compound Nodular Band, and in the clay just above and below that stratum, and possibly also higher. Its resemblance to the original figure of Sowerby is not so great as to the figure given in Goldfuss (Petrefact. pl. 118. fig. 1), with which it agrees very closely. In the different public collections of Speeton-Clay fossils this shell has received various names, as *A. macroptera*, Röm., *A. multicostata* (Leckenby), &c. The wide range in time of this species makes its reappearance in these beds less remarkable.

INOCERAMUS VENUSTULUS, Bean, MS., and I. IMBRICATUS, Bean, MS.

These shells occur plentifully in the upper part of the zone of *Amm. noricus*, and are, I believe, confined to this part of the section. I am inclined to think that there is only one species—the coarsely-striated *I. imbricatus* being the adult form, and the smooth polished *I. venustulus* the young form of the same species.

Astarte senecta, Bean, MS.

This *Astarte* seems to have been identified with *A. laticosta*, Deshayes, but it is very doubtful if this determination is correct. It is confined at Speeton to a certain part of the zone of *Bel. lateralis*; and, though common there, being incrusted in rapidly decomposing pyrites, it is difficult to obtain serviceable specimens. The same species occurs in the Lincolnshire area. The name is sometimes misprinted *Astarte sinuata.*

Isocardia angulata, Phil.

This small shell, which is very abundant at Speeton, has a wide range, occurring in all except the lowest beds of the zone of *Bel. jaculum* and ranging upwards throughout the greater part of the zone of *Bel. semicanaliculatus*?

Echinospatangus cordiformis, Breyn. = Toxaster complanatus, Ag. (Judd) = Spatangus argillaceus, Phil.

I have already recorded the horizons at which I have found this fossil. The condition of its preservation—coated and sometimes quite concealed by pyrites, in beds in which small concretions of pyrites abound—makes it very difficult to detect, and further researches may extend its range. I believe the position now assigned to it at Speeton will bring that section into closer accordance with the Neocomian beds of France and Switzerland.

Pentacrinus (annulatus, Römer).

This Crinoid occurs plentifully in the Compound Nodular Band, in detached fragments, and also in the *Noricus*-beds, but I have not yet found it higher in the section.

Trochocyathus conulus, Phil.

The small coral which has been with some doubt referred to this Gault species occurs throughout the *Noricus*-beds, where, however, it is rare. I have not seen it in any other part of the section.

Foraminifera are very plentiful in many of the beds (especially in *D 1*, *C 8*, *C 6*, *C 3*, and in parts of *B*), but I am not aware that any work has yet been done on them.

Crustacea.

I am indebted to Dr. James Carter for the following notes on the specimens from my collection submitted to him.

" Meyeria ornata, Phil.

" Of this characteristic and beautiful species I can give but little additional information. It is desirable to ascertain the conformation of the chelæ of the first pair of limbs—whether they are mono- or didactylous.

"MEYERIA FALCIFERA, Phil. MS.

"Syn. *Astacodes falcifer*, Bell.

"This species has given me much difficulty. Your specimens, as also those in the York Museum, offer characters which agree with those of *Meyeria* so precisely that I propose to retain the generic name given by Phillips. Bell has assigned to it (Pal. Soc. Mem.) an abdomen which does not belong to it, but to a totally distinct crustacean........his description needs very considerable reconstruction and correction.

"HOPLOPARIA PRISMATICA, M'Coy.

"I have compared your example with M'Coy's type specimens in the Woodwardian Museum, which are very good ones and are from Speeton. This species varies a good deal both in size and in degree of development of several of the characters.

"PALINURIDIA SCARBURGENSIS, Carter, MS.

"The specimen which I named a year or so ago is in the Scarborough Museum, and a fragment of the same species is in the York Museum. I hope shortly to describe and figure it, but may have occasion to alter the name, as I have an idea that the name of the genus is already employed."

DISCUSSION.

Prof. JUDD congratulated Mr. Lamplugh upon the important work he had accomplished. During his own frequent journeys to the coast he had seldom found the beds exposed on the shore, whilst the Author, by visiting the section in winter, had been able to make some interesting discoveries. He himself had mainly worked the cliff, Mr. Lamplugh the shore. He had adopted Ammonites, Mr. Lamplugh Belemnites, as the basis of classification; nor had he acted at hazard in rejecting the latter, since in studying the Neocomian elsewhere he had found correlation by means of Ammonites more satisfactory. He especially congratulated the Author on the light he had thrown upon the top and bottom of the section; at the top of the bottom section neither Mr. Leckenby nor he had any suspicion that there was any second coprolite-bed. As regards the top of the section the presence of Lower-Gault fossils was very interesting.

Mr. STRAHAN stated his belief that the existence of a partial barrier between the Lincolnshire and Yorkshire areas is indicated long before the Kimeridge-Clay period. For nearly all the Secondary rocks, up to the Chalk, tended to thin away in the ground separating the two areas. It was interesting to find a passage up from the Neocomian strata into the Red Chalk in Yorkshire as well as in Lincolnshire.

Prof. BLAKE alluded to the confusion in the Speeton Clay. He considered the coprolite-bed of importance as containing *remanié* Portlandian fossils. It was difficult to believe there was no un-

conformity here; at least there was a palæontological unconformity, if not a stratigraphical one.

Mr. Hudleston also alluded to the terrible confusion in Filey Bay, and to the difficulty of obtaining more than a glimpse of the rich fossil beds of the Speeton Clay. The section was remarkable in the apparent sequence from Upper Jurassic through Lower Cretaceous into Upper Cretaceous; but he thought there existed unconformities in time, as indicated by change of fauna, which were sometimes more important than those which made a greater impression on the eye. Such were frequently marked by nodule-beds, as was the case at the top and bottom of the Author's *Lateralis*-zone. Underlying the lowest of these nodule-beds the clays were undoubtedly Kimeridgian, whilst above it was an almost total change of fauna. He did not believe in the existence of true Portlandian beds in Yorkshire. These were really limited in extent, but there was a large part of the equivalents of our Kimeridge Clay which were called Portlandian by continental geologists. Much of this was below the Upper Kimeridge. Hence the *Lateralis*-zone could not be on that horizon. What, then, is this zone with the so-called *Amm. Gravesianus* and *Amm. gigas* in its uppermost portion? There was nothing like it in this country that he knew of, and it appeared that we must go to Russia for the analogues. The top of Mr. Lamplugh's section was equally interesting, as indicating, amongst other things, the probability of the Red Chalk of Speeton being only of Upper-Gault age. The paper was another instance of the value of close observations conducted over a long period of time.

Mr. Herries could confirm Mr. Lamplugh's account of the so-called "Middle Kimeridge" beds. He failed to understand why the Middle Neocomian should be abolished. He alluded to some beds on the shore, which by their fossils seemed to indicate a passage from the Upper Kimeridge to the *Bel. lateralis*-beds.

The Author, in reply, spoke of the advantage of using Belemnites for his main divisions, as the types in this case were so distinct, and 120 feet of beds were characterized by the easily recognizable *B. jaculum*. He thought the beds were more easily identified in this way, though the range of Ammonites (which often overlapped each other) had been traced as far as he was able. With the Belemnites also came in the principal changes in the fauna. There was a change of fauna several times in the section, and sometimes without nodular bands. The Kimeridge beds in Lincolnshire were similar, the Neocomian dissimilar. Besides the supposed *remanié* Portlandian forms in the lower coprolite-bed, there was a passage upwards of certain Jurassic fossils, such as *Avicula inæquivalvis* and *Pecten lens*. The Speeton "Portlandians" are believed to represent the "Upper Volga beds" of the Russians. With respect to the Gault forms, the gradual change is a good evidence in support of passage.

[*To face* p. 618.

eton Clay, arranged to a S

izons united by coloured lines.)

G. S. vol. xxiv. p. 231 (1868).

889.

JDD, 1868.

COMPLETE.

Ammonites Astierianus.
Amm. multiplicatus.
Amm. hystrix, &c.
Belemnites lateralis.

Exogyra subsinuata (vars.).

Toxaster complanatus.

esianus.

ateralis, Exogyra sinuata, var.,
a articulata.

teralis, Lingula ovalis ?

(D.)
Zone of
Belemnites lateralis.

nconformity ?

sp., *Arca* ?, *Lucina* ?, &c. (casts).

Lucina portlandica, Lithodo
Arca, Nucula, Ammonites
rians.

Ammonites gigas, Amm. Gi
sianus, Amm. giganteus ?

dules and many crushed fossils.
gula ovalis, Discina latissima,

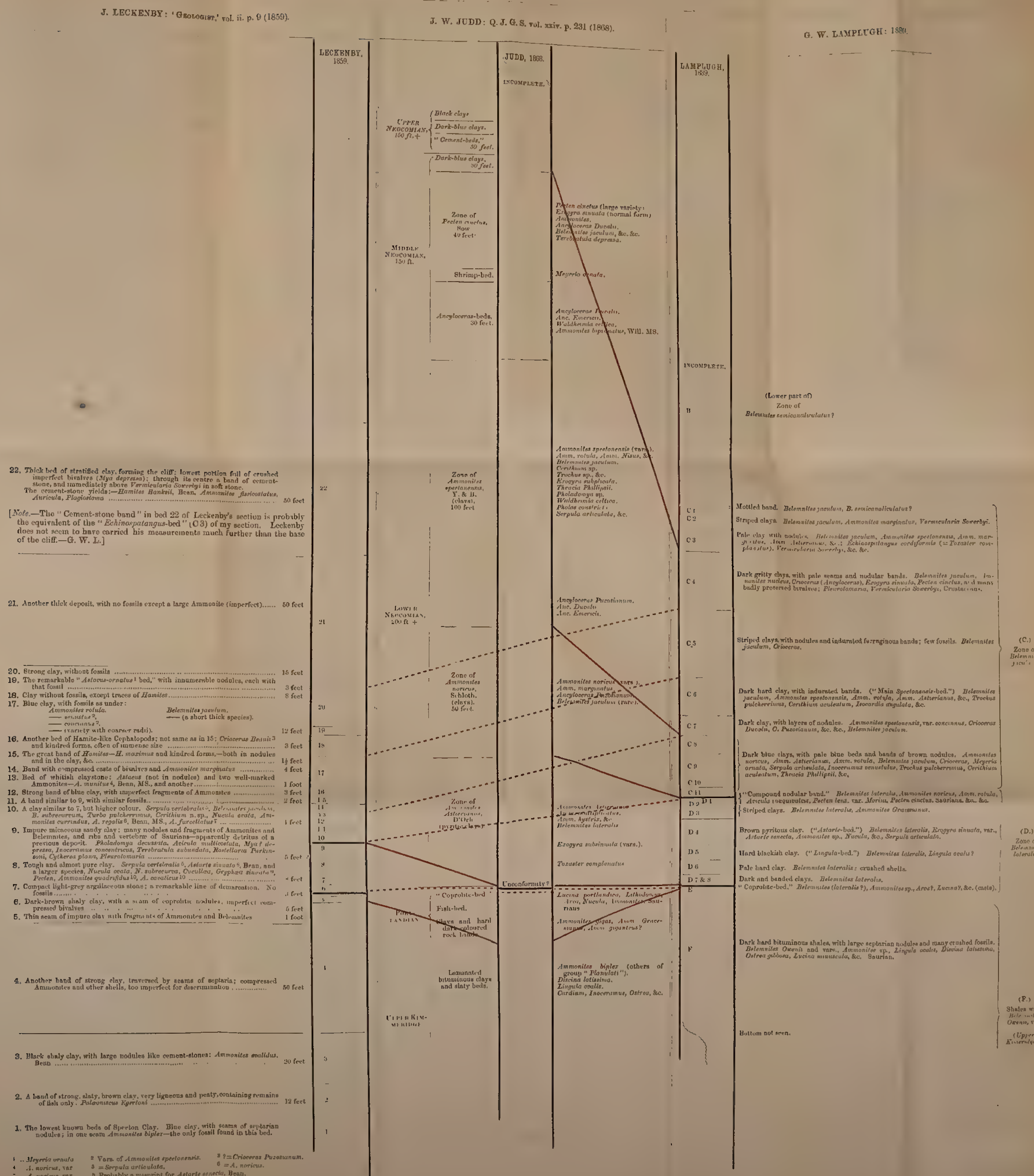
Ammonites biplex (others
group "*Planulati*").
Discina latissima.
Lingula ovalis.
Cardium, Inoceramus, Ostrea

(F.)
Shales with
Belemnites Owenii, var.

(*Upper Kimeridge.*)

Fig. 2.—*Comparative Sections in the Speeton Clay, arranged to a Scale of* 1 inch to 30 feet.

(Corresponding horizons united by coloured lines.)



[*To face* p. 618.

ram-Sections o

ed bivalves.

semicanaliculatus ?

eras, shells, wood.

fossils.)

eras (very large species).

jaculum ? (small form: rare).

II, *Pratt*,

ula subangulata, &c.; *Echinospatangus cordiformis* (one spm.).

ceras, *Exogyra*, shells.

semicanaliculatus ?, *Vermicularia Sowerbyi*, &c.

minuscula, *B*.

semicanaliculatus ?, *Bel. jaculum*.

e of *Bel. jaculum*.

ovalis : many

Figs. 3–8.—*Diagram-Sections of the Specton Clay, in ascending order.*

Fig. 5.—*Section of the Clays of the Zone of* Belemnites jaculum (*Lower Neocomian*) *at Speeton. Measured on the shore off Black Cliff and at the foot of the cliff.* (Scale 1 inch to 15 feet.)

C. Zone of Belemnites jaculum, *Phil.*, including subzones of *Ammonites speetonensis*, Y. & B., and *Ammonites noricus*, Schloth.

		Thickness ft.	in.	
	Clays with *Belemnites semicanaliculatus?* See fig. 6.			
C. 1	Dark mottled clay: pale markings	...	6	*Belemnites jaculum* and *Belemnites* sp. (*semicanaliculatus?*).
	Pale mottled clay: dark markings	...	4	*Bel. jaculum.*
	Dark gritty clay, with pyrites	1	...	
	Pale blue clay	1	...	
	Dark clay	1	6	*Bel. jaculum, Vermicularia Sowerbyi, Amm. marginatus?*, &c.
2	Pale clay	1	...	
	Darker seam	...	4	
	Pale bed, with iron stain and nodules	1	9	
	Dark clay	2	...	
3	Pale blue clays, with a band of nodules in a browner seam: smaller nodules throughout	8	...	Echinospatangus-bed.—*Bel. jaculum, Ammonites speetonensis, Amm. Astierianus. Amm. marginatus, Amm. nucleus. Echinospatangus cordiformis*, Breyn.=*Toxaster complanatus*, Gmel., in the brown band (see list, p. 597).
	Thin seam of pale greenish stone: weathers red	...	4	
	Dull black clay, with glauconite	3	...	*Bel. jaculum* in clusters, *Vermicularia Sowerbyi*, &c.
	Very pale clay, with large brown nodules	2	...	*Bel. jaculum, Amm. nucleus, Pecten cinctus*, Crustaceans, &c.
	Dark clay	1	...	*Bel. jaculum*, Oysters, and other shells plentiful.
	Thin seam of pale mottled yellowish stone and clay	...	3	
	Striped clays, with nodules in places	5	...	*Bel. jaculum*: few fossils.
4	Pale clay	...	6	
	Dark shaly clay: brown nodules	3	...	Badly preserved *Ammonites* and *Crioceras* (*Ancyloceras?*).
	Irregular indurated band of soft ironstone and clay	...	9	
	Dark shaly clays, with pyrites	6	...	Fossils abundant: *Bel. jaculum, Amm. nucleus*, Oysters of different kinds, *Rhynchonellæ*, &c.
	Indurated band, with round brown nodules	...	6	
	Striped clays	2	6	*Bel. jaculum.*
	Indurated brown gritty band	1	...	
	Very pale blue clay	...	6	
	Black hard shaly clay, rather pyritous	3	6	*Bel. jaculum*: large bivalves (crushed): few fossils.
	Soft pale grey or greenish beds, indurated in places	3	...	
	Alternations of pale and dark clays: oval brown nodules	10	...	
5	Light slaty-grey and reddish beds, with indurated band at top and very pale clay at base	4	...	Few fossils: *Bel. jaculum, Crioceras, Rostellaria* sp.
	Dark bluish clay: brown nodules	6	...	
	Irregular indurated ironstone band	...	9	*Ammonites rotula.*
	Dark splintery hard clay, with a few brown nodules	9	...	Main Speetonensis-bed: many fossils. *Bel. jaculum, Ammonites speetonensis* and vars. *venustus* and *concinnus, Amm. rotula, Trochus pulcherrimus*, &c. (see list, p. 591)
6	Band of brown nodules: indurated in places	...	6	
	Dark, somewhat striped clays, with nodules, tending to form indurated bands	6	...	*Bel. jaculum* &c.
	Indurated ironstone band, in pale clay	...	6	*Crioceras* (*Ancyloceras?*): a large species (*C. Duvalii?*).
7	Dark clay, with a pale stripe	4	6	
	Indurated band, in pale clay	...	5	*Crioceras* abundant: a smaller species.
	Dark hard clays: somewhat striped	3	...	*Bel. jaculum* (large), *Amm. speetonensis*, var. *concinnus.*
	Pale brownish-blue band, with round brown nodules	...	6	
8	Dark blue clays: somewhat striped	6	...	*Bel. jaculum, Amm. noricus, Amm. Astierianus, Amm. rotula, Trochus pulcherrimus*, &c. &c. (see list, p. 597).
9	Two pale nodular seams, with black clay between	3	6	As above, and *Inoceramus venustulus*, Bean, MS. *Meyeria ornata*, &c.
	Dark blue clay; black at top	6	...	
	Band of oval-brown nodules; Pale blue or slaty-grey beds	3	...	*Bel. jaculum, Amm. noricus*, &c.
10	Green and mottled seam (glauconitic)	...	3	*Bel. jaculum, Amm. noricus*, &c.
11	Dark blue clays with streaks of green and black grit	1	...	*Bel. jaculum, Amm. noricus, Crioceras, Pecten lens*, var. *Meyeria, Astarte* sp. &c.
D. 1	Compound nodular band: see fig. 4	...	...	Band of shells and crushed Ammonites. *Amm. noricus, Bel. lateralis*, &c.
	Clays with *Bel. lateralis.*			

Zone of *Ammonites* sp. ... Y. & B. ... Schloth.

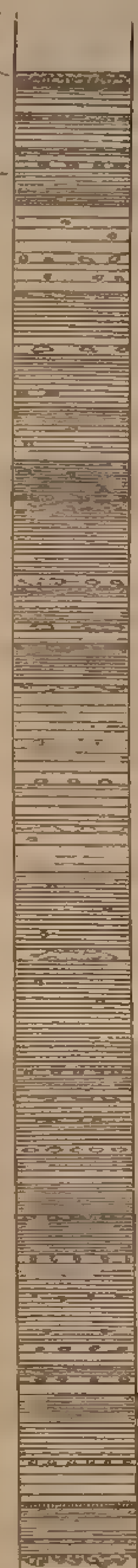


Fig. 4.—*Section of the Clays between the* "Compound Nodular Band" *and the* "Coprolite-bed" *at Speeton. Measured in shore-exposures off Black Cliff.* (Scale 1 inch to 15 feet.)

D. Zone of Belemnites lateralis, *Phil.*

		Thickness ft.	in.	
	Dark clay, with *Bel. jaculum.* See fig. 5.			
D. 1	"Compound Nodular Band": large and small nodules and black phosphatic stones in dark clay	1	...	*Belemnites lateralis, Ammonites noricus, Pecten cinctus, Crioceras*, and many fossils (see list, p. 591).
2	Dark gritty clay, full of fossils: many small nodules and black stones	4	...	*B. lateralis.*
3	Pale brown nodular bed: ferruginous [illegible]	...	6	*B. lateralis, Exogyra sinuata, Avellana obsoleta*, &c.
	Brown, pale, and striped clay	3	...	*Ammonites Gravesianus*, D'Orb.
	Pale clay, with brown nodules	...	6	
4	Hard, dark brownish, pyritous clays: fossils abundant in the upper half	10	...	Astarte-bed.—*B. lateralis, Ammonites* sp., *Exogyra sinuata* (= *Couloni*, Judd), *Astarte senecta* (Bean, MS.), &c. (see list, p. 591).
	Soft slate-coloured or brownish clay	1	...	
5	Hard blackish clay, with some bright pyrites	5	...	Lingula-bed.—*B. lateralis, Lingula ovalis?, Pinna?*
6	Pale indurated clay, striped and mottled: towards centre forming a soft stone	4	6	Pale beds.—*B. lateralis* and vars., *Ammonites* sp.: crushed bivalves.
	Mottled seam	...	7	
7	Striped pale blue, brown, and mottled beds	3	...	
	Dark blue clay, with bright blue mottling	...	4	*Belemnites lateralis*: shell-fragments.
	Greenish-black clay, with hard pyritous nodules	...	8	*Belemnites*, much worn: bone.
	Greenish-black clay: small black pebbles	...	10	*B. lateralis?, Ammonites* sp., *Rhynchonella*, casts of shells
	Hard black shale	...	10	
E.	"Coprolite-bed": a stony band of black and brownish nodules	...	4	
	Shales with *Bel. Oweni*; see fig. 3.			

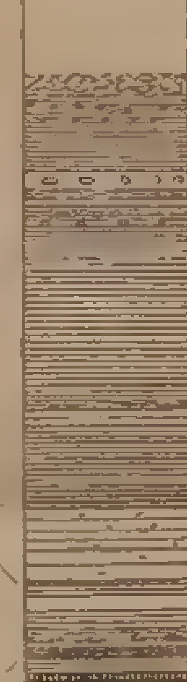


Fig. 3.—*Section in Shales below the* "Coprolite-bed" *at Speeton. Measured on the shore off the northern part of Middle Cliff, Feb. 14th, 1883.* (Scale 1 inch to 15 feet.)

F. Bituminous Shales, with Belemnites Oweni, *Pratt*, and varieties.

	Thickness ft.	in.	
"Coprolite-bed"	...	4	See fig. 4.
Black shaly clay, with occasional septarian nodules	3	...	Fossils rare: *B. Oweni*, var.; *Ammonites* sp.
Sr. l l la k sl ale			Crushed fossils plentiful: *Ammonites biplex?, Lucina minuscula, B. Oweni* and vars., &c.
Lighter shaly clay: bluish			
Dark blue shaly clay	3	...	
Hard brownish ferruginous shale	1	...	
Blackish shaly clay	1	...	Crushed fossils abundant.
Hard brown shale, with large round septaria	2	...	
Dark fossiliferous shale	9		*Ammonites, Ostrea gibbosa, Discina latissima, Lingula*, ... small bivalves, fish-scales?, &c. (see list, p. 593)
Hard brown shale, with septaria	1		
Dark shale			Bones of Saurian
Hard brown shale, with nodules		6	
Softer shaly clay: first darker, then lighter than above	2	...	
Greyish shale, speckled with fossils			
Similar beds extended lower, but were not measured			

Upper Kimmeridge and Portlandian of Judd.

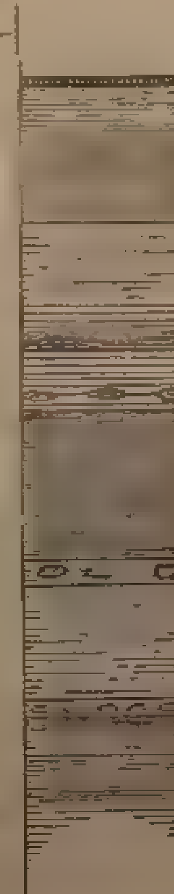


Fig. 8.—*Section of Beds between the Red Chalk and Clays of the Zone of* Belemnites semicanaliculatus?, *as seen in Slips at the Cliff-foot between Speeton Gap and Crab Rocks.* (Scale 1 inch to 15 feet.)

A. Lowest part of Zone of Belemnites minimus, *List.*, and allies.

	Thickness ft.	in.
? Red Chalk (slipped), crushed		
Mottled marly shale, with bright green streaks	2	...
Dull reddish clay, with yellow and green streaks	...	6
Streaked, brown, gritty marl	...	3
Bright yellow and grey marl, with ... nodules	...	3
Striped brownish shaly clay	...	6
? Neocomian: Black clay ... seen about	3	...

Belemnites semicanaliculatus?

Fig. 7.—*Section through the* "Cement-beds" *on Speeton Beck Ridge.* (Scale as above.)

"Cement-beds" (Base of Upper Neocomian of Judd).

B. Zone of Belemnites semicanaliculatus? and allies. (Upper part.)

INTERVAL NOT SEEN (say 50 ft)

	Thickness ft.	in.	
Black clays; Band of nodules	1		Fossils rare.
Striped pyritous clays ... about	9	...	
Red weathered clay	1		*Belemnites.*
Hard striped blue clays	1		
Band of large nodules in weathered red clay	1		
Darker clay, with some pyrites	4	...	Many small shells.
Band of large "cement" nodules in dark clay	3	...	Many shells. *Panopæa neocomiensis, Cucullæa securis, Isocardia angulata, Belemnites*, &c.
Very pale hard clay	3	...	
Black clay	6	...	Many shells and *Belemnites* in nests or bands.
Hard pale semi-nodular band	...	10	*Belemnites semicanaliculatus?*
Black pyritous shale with yellow efflorescence	...	6	
Blackish clay, with scattered pyrites	3	6	Many shells in nests and layers as above, &c.
Hard paler clay-band, with some nodules	...	6	A layer of *Belemnites, Exogyra, Vermicularia Sowerbyi*, &c.
Rather pale striped clays, with scattered nodules seen for about	+10		

INTERVAL NOT SEEN

Fig. 6.—*Section of the Lower Part of the Zone of* Belemnites semicanaliculatus?, *measured in Black Cliff and on the shore opposite.* (Scale as above.)

(Part of) Middle Neocomian of Judd.

	Thickness ft.	in.	
			Rostellaria Parkinsoni, Cucullæa securis, Isocardia angulata.
Black clay, with bright pyrites ... seen	+9	...	*Nucula* sp., &c. &c.
			Belemnites sp.
Striped clays, with large brownish nodules ... about	16	...	*Belemnites semicanaliculatus? Vermicularia Sowerbyi. Isocardia angulata*, &c. &c.
Band of large pale cement-nodules, with fossils	1	...	*Belemnites, Lima*, &c. &c. (see list, p. 622)
Black clay, with nests of bright pyrites ... about	9	...	(Few fossils.)
Band of decomposed pyritous nodules	1	...	
Dark striped clays, with pale scattered nodules and much pyrites ... about	15	...	*Bel. semicanaliculatus?, Nucula subangulata*, &c. (Few fossils.)
Paler seam, with pale nodules	1	...	*Bel. semicanaliculatus?*
Dark clay ... about	10	...	*Crioceras*, shells, wood. (Few fossils.)
Paler beds, with two lines of large nodules	6	...	*Crioceras* (very large species). *Bel. jaculum?* (small form: rare).
Dark clay	5	...	
Paler clay, with large brown nodules	1	...	*Nucula subangulata*, &c.: *Echinospatangus cordiformis* (one specimen).
Dark clay	4	...	
Paler beds, with dark bands	4	...	*Crioceras, Exogyra*, shells.
Dark clay	5	...	*Bel.* ..., *Vermicularia Sowerbyi*, &c.
Pale clay, with brown nodules and ferruginous stain	1	3	
Mottled bands (top of *B. jaculum* zone): see fig. 5	...	6	*Bel.* ... Zone of *B.* ...

Note. ... measured only in the great slips, ... somewhat doubtful.

37. Descriptions *of some* New Species *of* Carboniferous Gasteropoda. By Miss Donald, of Stanwix. (Read June 19, 1889.)

(Communicated by J. G. Goodchild, Esq., F.G.S., of the Geological Survey.)

[Plate XX.]

With one exception the Gasteropoda described in this paper have been collected by Mr. John Young, Hunterian Museum, Glasgow. The specimens are all very minute and are well preserved, their creamy colour giving them the appearance of shells of a much more recent date than the Carboniferous period. With the best of materials, however, the affinities of the Palæozoic Gasteropoda are always more or less difficult to determine. In this instance though the sculpture of the surface is wonderfully well preserved, none of the apertures are entire, and the minute size of the shells renders it difficult in many instances to discern the lines of growth.

Out of the five Scottish shells three are undoubtedly *Murchisoniæ*, one in particular having the band indicating the sinus in the outer lip very clearly defined.

With regard to the other two shells, I know of no genus to which they may be referred, unless it be *Orthonema*, Meek and Worthen*. The more elongated shell bears some resemblance to species of the genus *Aclisina*, de Koninck †, from which it differs, however, in the form of the mouth and the flattened, closely coiled whorls.

Before proceeding to discuss the general characteristics of the shells, it may be well to give the original description of the genus *Orthonema*:—

"Shell elongate, many-whorled; volutions ornamented with revolving carinæ crossed by nearly straight lines of growth; body-whorl short, not produced below; aperture angular above, slightly effuse below; peristome incomplete; lip simple, nearly straight; axis imperforate. The shell upon which we propose to found this genus has much the appearance of a *Murchisonia*, but differs in being entirely destitute of a spiral band or a sinus in the lip, as in that genus and *Pleurotomaria*, the lines of growth being distinctly seen crossing the carinæ and the spaces between, without making the slightest curve."

In the form of the spire and in ornamentation both the shells agree with the above description, the lines of growth also come straight down over the keels. With regard to the mouth, it is angular above and slightly effuse below, the peristome is incomplete; the pillar-lip, however, seems somewhat more developed than is repre-

* Proc. Acad. Nat. Sci. Phil. 1861, p. 146.

† Faune du Calc. Carb. de la Belgique, 1881, vol. vi. pt. 3, p. 86.

sented in the figure of the type species *Orthonema Salteri* *. Great stress cannot be laid on this difference, as the mouth is not well drawn, and it may not have been sufficiently well preserved to admit of more careful delineation.

Both the Scottish shells are very minute, but they do not differ more in size from the type than do some species of *Murchisonia* from one another, and they are about the same size as *Orthonema subtæniatum*, Geinitz †, one of the smallest species I have seen described. Some of the Spanish species also seem to be very small, for Barrois ‡ says that the specimens he has collected of *Orthonema Choffati* vary in length from 2 millim. to 20 millim., while the length of *C. Delgado* ranges from 3 centim. to 8 or 9 millim.

ORTHONEMA PYGMÆUM, sp. nov. (Pl. XX. figs. 1, 2.)

Shell very minute, turreted, composed of from seven to nine angular whorls. Each whorl is ornamented with four keels, and on the body-whorl there is an additional fine keel below. The second keel from the top is generally the strongest, but sometimes that next below is equally strong, the uppermost and the lowest are the slightest. The mouth is a little longer than wide, and slightly effuse below; the pillar-lip is thickened and arched forwards. There is no evidence of a sinus in the outer lip; the lines of growth come directly down the whorls, merely being deflected by the keels. The base is rounded.

Length from 2 to 2½ millim.; width of the body-whorl about 1 millim.

This shell bears a strong resemblance to *Orthonema subtæniatum*, Geinitz §, but differs from it in possessing stronger keels, which divide the whorls into unequal spaces; and also the whorls are not so rounded as in that species.

Locality. Glencart, Dalry, Ayrshire.

Formation. Upper Limestone series, which represents the middle beds of the Yoredale rocks.

? ORTHONEMA YOUNGIANUM, sp. nov. (Pl. XX. figs. 3, 4.)

Shell small, very elongated, conical, composed of from eleven to fourteen whorls. The whorls are closely set, and the outline of the spire is somewhat convex. Each whorl is ornamented with three or four keels, generally with four, the spaces between them vary in width; in some specimens the two middle keels are the strongest, in others only the lower of the two. The mouth is rounded and slightly effuse below, the lip is turned back on the pillar, which is arched forward. The base is somewhat flattened and smooth. The lines

* Geol. Surv. Illinois, 1866, vol. ii. pl. xxxi. fig. 14.

† Dr. H. B. Geinitz, 1866. Carbonformation und Dyas in Nebraska, p. 12, pl. i. fig. 18.

‡ Recherches sur les Terrains Anciens des Asturies et de la Galice, 1883, pp. 352–354, pl. xvii. figs. 21, 23.

§ *Murchisonia subtæniata*, H. B. Geinitz, 1866, Carbonformation und Dyas in Nebraska, p. 12, pl. i. fig. 18. *Orthonema subtæniata*, Hayden, Final Report on Nebraska (1871), p. 228.

of growth are not very distinct except on the base; they appear to come straight down the whorls, being merely deflected by the keels.

Length of small specimen of twelve whorls 4 millim., width of body-whorl $1\frac{1}{4}$ millim. A larger specimen has only four whorls preserved, it is 3 millim. in length, and the body-whorl is $1\frac{1}{2}$ millim. in width.

This shell bears some resemblance to species of *Murchisonia*, but the absence of a sinus in the outer lip excludes it from that genus; from species of *Aclisina* it may be distinguished by the form of the mouth and the flattened, closely set, whorls. I feel somewhat doubtful about referring it to the genus *Orthonema*, as it is more elongated and the whorls are less angular than in any species of that genus I have seen figured; I, however, know of no other genus to species of which it bears a closer resemblance, and it may therefore be well to place it with *Orthonema* for the present.

Locality. Glencart, Dalry.

Formation. Upper Limestone series.

It is, I think, unnecessary to repeat a description of the genus *Murchisonia* here, as it was pretty fully given in a previous paper *, in which also I mentioned that J. W. Salter had separated from the typical *Murchisonia* a group of shells distinguished by certain characteristics under the name *Hormotoma* †, and that Whitfield had formed a distinct genus of others under the name of *Lophospira* ‡. Since then D. P. Œhlert has grouped some species of *Murchisonia* in two more sections, called *Goniostropha* and *Cœlocaulus* §.

To the former of these alone I need refer in this paper.

In the section *Goniostropha* Œhlert collects all those species which are turriculated, elongated, having angular whorls of which the sinual band, nearly always limited by two prominent keels, occupies the summit; sometimes there are additional spiral keels. He says that the spire has no umbilicus, and at the same time he refers to this section *Murchisonia kendalensis*, M'Coy, which has an umbilicus. Much weight, however, cannot be attached to the presence or absence of an umbilicus, as it is known to exist in some members and not in others of the same species.

Of the species I am about to describe, one, *M. subtilistriata*, may undoubtedly be referred to this section; and another, *M. turriculata*, De Kon., may at any rate be placed here provisionally, as it agrees in general characteristics, with the exception of the sinus being most probably situated immediately below the angle. With regard to the remaining species *M. compacta*, its characteristics are such as to entitle it to a place in a separate section.

* "Notes upon some Carboniferous Species of *Murchisonia* in our Public Museums," Quart. Journ. Geol. Soc. Nov. 1887, p. 620.

† Geol. Surv. Canada, dec. i. p. 18.

‡ Bull. Amer. Mus. Nat. Hist. vol. i. no. 8. 1886, p. 311.

§ Bull. de la Soc. d'Etudes Scientifiques d'Angers, 1887, pp. 13, 20.

Section Goniostropha, Œhlert, 1888.

Murchisonia (Goniostropha) turriculata, De Kon. (Pl. XX. fig. 5.)

Murchisonia turriculata, De Koninck, 1883, 'Faune du Calcaire Carb. de la Belgique,' p. 19, pl. xxxiv. figs. 11, 12, 13.

Murchisonia angulata, var., De Koninck, 1843, 'Descr. des Anim. Foss. du Terr. Carb. de la Belgique,' p. 412, pl. xl. fig. 8.

A fragment of a shell, consisting of four whorls, seems to agree in all essential particulars with one described and figured by De Koninck as *Murchisonia turriculata*. If entire it would be elongated and composed of numerous angular whorls. The specimens described by De Koninck have from sixteen to eighteen whorls. There is a prominent keel about the centre of each whorl, and below it there are two finer keels placed at about equal distances from it and from each other; on the lowest whorl preserved there is evidence of a still finer keel appearing above the suture. De Koninck does not mention the presence of this lower keel on his specimens, but there are more numerous keels on the shell previously described by him as *Murchisonia angulata*, var., which has since been identified by him with *M. turriculata*. And in other instances the number of keels on different individuals of the same species is observed to vary. The presence or absence of a keel cannot therefore be considered of much importance when shells agree in other particulars. On the upper part of the whorl there is a much finer keel, placed somewhat nearer to the suture than to the central keel. De Koninck says this keel is in the middle of the upper part of the whorl in the specimen figured by him; it, however, seems to vary in position on different individuals in the Brussels Museum, being higher on some and lower on others. The surface of the whorls is almost flat both above and below the principal keel. The lines of growth are indistinct, so that no evidence of the position of the sinus can be obtained from this specimen. De Koninck says it is situated between the strongest keel and that next below. The mouth is not preserved. De Koninck describes that of the Belgian specimens as round. My specimen is crushed, so the spiral angle cannot be accurately ascertained.

I believe this is the first record of this species being found in Britain.

Length of fragment of four whorls $10\frac{1}{2}$ millim., width of lower whorl one way $6\frac{1}{2}$ millim.; in the opposite direction 4 millim.

Locality. Abbey Foss, Askrigg, Yorkshire.

Formation. Shales at the base of the Yoredale rocks.

Murchisonia (Goniostropha) turriculata, var. scotica. (Pl. XX. fig. 6.)

A fragment of a shell of which about six gradually increasing whorls are preserved seems to agree with that last described except in its much smaller size. This difference in size is so great as quite to constitute a variety, if not a distinct species. The position and

number of the keels is the same, with the exception of the strongest keel being situated a little higher on the whorl than in the typical *M. turriculata*; the additional fine keel is visible on the three lower whorls. The sutures are rather more prominent than in *M. turriculata*, De Koninck, and also than in my larger specimen. The lines of growth are well preserved on the lowest whorl; they curve back to the strongest keel, are invisible between it and the keel next below, and then curve forward again. The sinus is probably situated between the strongest keel and that next below, but the apex and the base of the shell are broken.

Length of fragment consisting of six whorls $5\frac{1}{4}$ millim., width of lowest whorl $2\frac{1}{2}$ millim.; it is slightly broken, therefore this measurement is somewhat less than it would be were the whorl entire.

Locality. Dalry.

Formation. Upper Limestone Series.

MURCHISONIA (GONIOSTROPHA) SUBTILISTRIATA, sp. nov. (Pl. XX. figs. 7, 8.)

Shell small, very elongated, consisting of numerous whorls. Each whorl has a strong angle a little below the middle, and on this angle there is a prominent keel. About midway between this keel and the suture there is another keel; between these keels there are two strong threads, and below the lower keel there are one or two strong threads between it and the suture. There is also a very faint line about midway between the angle and the upper suture. The lower part of the whorl is almost flat and slopes rapidly down to the suture, which is deep. The upper part of the whorl is slightly convexo-concave in adult specimens, but in young ones it is more convex, the concavity above the angle being hardly discernible. The lines of growth are not well preserved on any of the specimens; on the penultimate whorl of the largest specimen there are traces of lines of growth curving forward below the strongest keel. This keel probably represents the sinus in the outer lip. The base of all the specimens I have seen is broken, therefore the form of the mouth is unknown.

There are three specimens of this shell in the collection of Mr. Young, Hunterian Museum, Glasgow, and I have a fragment which was given me by him. The largest specimen (Pl. XX. fig. 7) consists of eleven and a half whorls; both the apex and base are broken. Its length is $8\frac{1}{2}$ millim., width of body-whorl $3\frac{1}{2}$ millim. Length of fragment (Pl. XX. fig. 8), consisting of three whorls, $3\frac{1}{4}$ millim.

Locality. Glencart, Dalry.

Formation. Upper Limestone Series.

Section STEGOCŒLIA.

Whorls angular, keeled; sinus wide, situated on the posterior part of the whorl above the angle, umbilicated when young; inner lip reflected on the columella and forming a callosity round the base of the pillar, covering the umbilicus in adult specimens.

MURCHISONIA (STEGOCŒLIA) COMPACTA, sp. nov. (Pl. XX. figs. 9–13.)

Shell small, short and conical, composed of from six to nine whorls. The whorls are almost convex, being but slightly angular. A little above the centre of each whorl there is a strong keel, below which there is another almost equally strong, and just above the suture there is a third and slighter keel; the space between the two uppermost is the greatest. Below the suture there are two very fine keels placed close together, occupying about half of the upper surface of the whorl and leaving a wide space between them and the strongest keel. This space seems to have been formed by the successive filling up of the sinus in the outer lip, as indicated by the lines of growth, which are strongly arched and so fine that they are only to be observed on well-preserved specimens. On the rest of the shell the lines of growth are much stronger and may be distinctly seen curving back over the two uppermost keels and curving forward again below the strongest keel. Base of the shell rounded. Mouth rather longer than wide, slightly channelled below; outer lip reflected over the pillar; the inner lip is a thin shelly layer spread on the columella; it thickens at the base of the pillar and covers the umbilicus in adult specimens, in young ones the umbilicus is open.

Length of a medium-sized specimen about 4 millim., width of body-whorl 2 millim. A fragment of a larger specimen measures $2\frac{3}{4}$ millim. across the body-whorl, height of its body-whorl $2\frac{1}{2}$ millim.

This shell is shorter than is the case in most of the *Murchisoniæ*. Its ornamentation resembles that of *M. quadricarinata*, M'Coy, but it may easily be distinguished from that shell by its greater spiral angle and smaller number of whorls. It appears to be identical with some shells in the Brussels Museum from Visé marked *M. spirata*, Goldf.* I have, however, seen the type of this species in the Bonn Museum, and it is a totally different shell, being more elongated, and the ornamentation is quite distinct.

Locality. Glencart, Dalry.

Formation. Upper Limestone Series.

There is a single specimen of this species in the Jermyn Street Museum, marked No. TK, 1618. It is well preserved and consists of six whorls, the apex is, however, broken; if entire there would probably be two or three more whorls. One of the fine keels on the upper part of the whorl is wanting in this specimen. This may perhaps arise from the substance in which the shell is preserved being too coarse to retain it.

Length 3 millim., width of body-whorl $1\frac{1}{2}$ millim.

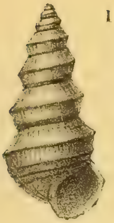
Locality. Cawledge Burn, $\frac{5}{8}$ of a mile N. of Cawledge Park, S. of Alnwick.

Formation. About the same horizon as the Yoredale rocks †.

* Petr. Germ vol. iii. p. 26, pl. 172. fig. 6, *a*, *b*.

† I am greatly indebted to Mr. John Young, Hunterian Museum, Glasgow, for his kindness in giving me every facility, whilst writing this paper, for studying his fine collection of Carboniferous Gasteropoda and also for the gift of many specimens.

Quart. Journ. Geol. Soc. Vol. XLV. Pl. [illegible]


1

× 12


2.

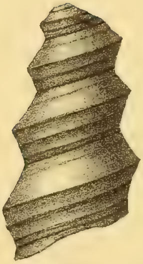
× 15.


3

× 12


4.

× 12.


5.

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6

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7.

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8.

× 8


9

× 12.


11.

× 8.


10.

× 10


12.

× 10


13

× 12

Miss J. Donald del. F. H. Michael lith. Mintern Bros. imp.

CARBONIFEROUS GASTEROPODA

EXPLANATION OF PLATE XX.

Figs. 1, 2. *Orthonema pygmæum*, sp. n., Glencart, Dalry: 1, front view, × 12; 2, back, × 15.

3, 4. *Orthonema* (?) *Youngianum*, sp. n., Glencart, Dalry. × 12.

5. *Murchisonia* (*Goniostropha*) *turriculata*, De Kon., Abbey Foss, Askrigg. × 3.

6. —— (——) ——, var. *scotica*, Dalry. × 8.

7, 8. —— (——) *subtilistriata*, sp. n., Glencart, Dalry: 7, adult, × 6; 8, fragment of young shell, × 8.

9–13. —— (*Stegocœlia*) *compacta*, sp. n., Glencart, Dalry: 9, back view, × 12; 10, apex, × 10; 11, mouth, enlarged, showing reflected inner lip, outer lip broken; 12, young shell showing open umbilicus, × 10; 13, × 12.

38. *On* Tachylyte *from* Victoria Park, Whiteinch, *near* Glasgow.

By Frank Rutley, Esq., F.G.S., Lecturer on Mineralogy in the Royal School of Mines. *With an* Analysis *of the* Rock, by Philip Holland, Esq., F.C.S., F.I.C. (Read June 19, 1889.)

In a paper published last year in the 'Transactions of the Geological Society of Glasgow' by Messrs. John Young, F.G.S., and D. Corse Glen, F.G.S.*, an interesting account is given of certain intrusive sheets and veins of dolerite passing through Carboniferous shales and sandstones, which contain the erect stems of fossil trees, determined by Mr. R. Kidston, F.G.S., as those of *Lepidodendron Veltheimianum* †. In one instance a thin vein of the dolerite was found to pass completely through one of the trees a little above the roots. There can therefore be no doubt that these dolerite veins were formed, as the authors point out, subsequently to the growth of the trees and the deposition of the surrounding beds.

In the paper already cited the authors duly recognize the tachylytic character which the margins of the smaller intrusive veins present in the following words:—

"In this quarry we have the interesting evidence that along these lines, especially in the thinner veins, the dolerite has cooled as a vitreous glassy lava, in which a thin layer, showing micro-spherulitic structure, has been developed during the process along the surface of both faces of the vein. These veins are now seen to have lost their glassy structure through devitrification, and are of a whitish colour, but their spherulitic structure, which still remains, clearly indicates that they once existed as veins of a glassy tachylyte. This is the first instance in which we have found such a structure amongst the dolerites of the Glasgow Coal-field."

I am indebted to the kindness of Mr. John Young for the specimens upon which this paper is based.

Of these the most important is one in which the entire thickness of the vein is shown, and to which the shale, forming one of the walls, is attached. The total thickness of the vein, with its tachylyte selvages, is about one inch. The vein itself is of a pale bluish grey to brownish grey, becoming greyish white along the margins where the spherulitic structure is best developed. A very narrow band, or rather film, of a partially vitreous character, lying between this and the shale, is of an ashy grey colour. The shale is black or dark bluish grey, and the planes of lamination are speckled with exceedingly minute scales of mica.

That portion of the section which is most remote from the contacts shows a confusedly crystalline structure, together with a small quantity of interstitial glass.

* "Notes on a Section of Carboniferous Strata containing Erect Stems of Fossil Trees and Beds of Intrusive Dolerite in the old Whinstone Quarry, Victoria Park, Lower Balshagray, near Whiteinch and Partick."

† *Ibid.*

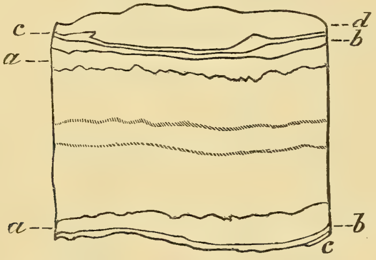
A tendency to spherulitic structure, through the radial grouping of small crystals or microliths, may be observed even in this part of the vein. These seem to consist chiefly of felspars, more or less altered, and there are, besides, a few micro-porphyritic crystals of augite and olivine, and some irregularly shaped spaces, now filled with calcite, which may in some cases be pseudomorphous after olivine, in others an infiltration-deposit in vesicles. The section is profusely speckled with minute opaque grains, which, in reflected light, appear white or yellowish white. This white matter may be partly kaolin, but in some instances it is apparently leucoxene, resulting from the alteration of ilmenite or titaniferous magnetite, the latter being rendered the more probable from the frequent occurrence of this white substance in the form of minute octahedra.

The crystallization in this central portion of the vein has a somewhat coarser character than in the marginal parts. Micro-porphyritic pseudomorphs are to be seen here and there; they consist of calcite, having a slightly rusty stain, and are sometimes bordered by a narrow zone of limonite.

In some cases they are pseudomorphs after augite. One section taken in the plane of symmetry gave the angle $100 : 001 = 74°$; another, approximately basal, gave the angle $110 : 1\bar{1}0 = 86°$.

In this portion of the vein what appear to be minute garnets are somewhat plentiful. They mostly occur in rounded grains, but small rhombic-dodecahedra may occasionally be detected.

Section of White-Whin Vein, Victoria Park, Whiteinch, near Glasgow. (Natural size.)



a a. Densely spherulitic bands.
b b. Colourless vitreous bands with spherules.
c c. Brown or coffee-coloured vitreous bands, showing distinct fluxion-banding and containing a few small spherules.
d. Dark shale. This has been broken away from the under surface of the specimen.

The central portion of the vein has a confusedly crystalline structure.

On passing from the middle of the vein towards the margin the proportion of opaque white matter diminishes, and an increase of vitreous material, coupled with a more marked tendency to spherulitic structure, is met with, a zone of densely packed spherules (indicated by the letter *a* in the accompanying figure) eventually resulting. This spherulitic zone ends abruptly, and is succeeded by

what must once have been an almost purely vitreous band (indicated by the letter *b*), which has, however, undergone a partial devitrification, seemingly by the development of globulites. Fluxion-structure is very well defined in places. There are a few isolated spherules in this band, and between it and the more densely spherulitic zone there is a sharp, but very irregular, sinuous line of demarcation slightly stained by ferric oxide. The band (*b*) appears very dark between crossed nicols, in spite of the devitrification, showing that a considerable amount of unaltered glass is still present.

This band is succeeded by another (indicated by the letter *c*), which is also vitreous in character, and is densely crowded with minute, opaque, white specks, which cause it to assume a bluish-white milky appearance when viewed in reflected light. When thus illuminated the belt is seen to be marked with irregular snow-white streaks, indicative of fluxion.

In transmitted light the belt appears of a yellowish-brown to reddish-brown or almost coffee-colour, while the fluxion-banding now stands out in dark, almost black, streaks. The difference in colour between this and the adjacent, nearly colourless band (*b*) is very marked.

In the coffee-coloured band (*c*) a few well-defined spherules also occur.

Between this and the Carboniferous shale there is a very persistent, irregular, finely crumpled, opaque line of a pale yellowish or reddish white. This line represents what appears to be the limit of fusion of the shale.

The bands *b* and *c* show great irregularity in their respective thicknesses, and occasionally one of them seems to thin out almost entirely. This is evidently due to the drag exerted upon the once viscous matter of the vein by the walls along which it crept, such a motion, and that an occasionally retarded one, being sufficiently evinced by the fluxion-banding.

To ascertain the relative fusibilities of the whin and the shale two small splinters were taken, one of whin and the other of shale, as nearly as possible of the same size and thickness, and were held side by side in the forceps and exposed to the blowpipe-flame for the same period and in the same part of the flame. An exposure of several seconds sufficed to fuse the extremity of the fragment of whin to a dark glass, while that of the shale was slightly fritted to a greyish enamel.

A further exposure to the flame resulted in the formation of more and of a darker glass on the shale than that previously developed; but it was at once evident that, of the two splinters, the whin produced the darker glass, and was the more readily fusible rock. The dark colour of the glass produced by the fusion of the whin in the blowpipe-flame is evidently due to further oxidation of the iron present in the rock, and which, as shown by the analysis, exists chiefly in the condition of protoxide.

The deep colour of the vitreous band in contact with the shale and the colourless character of the adjacent glassy one, which unques-

tionably belongs to the whin-vein, indicates that there is a difference in the chemical composition of the two bands, the deep colour of the glass in contact with the shale being probably due to the presence of metallic oxides in the latter rock. If this be so, the dark-coloured glass results from the fusion of the shale. It may be that this is merely the outermost glassy selvage of the whin-vein, tinted more or less by metallic oxides derived from a very slight incipient fusion of the shale. Assuming, for the moment, that this is the case, we have to account for the well-defined sinuous line of demarcation between the coloured and colourless bands of glass, and regarding these two bands as viscous matter of different densities, the existence of such a line, the trace of an undulating separation-surface, in a rapidly cooling magma is precisely what one would expect. A more perfect incorporation of the two glasses would have resulted in a lowering of tint and in the abolition of any such line of demarcation. The colourless glass may therefore be regarded as the tachylyte of the whin-vein, while the darker band I propose to distinguish by the term shale-glass.

As already pointed out by Messrs. J. Young and D. Corse Glen, a considerable variation in texture and colour is met with in the material constituting the intrusive veins at Whiteinch, and, to quote their own words, "Where thinner sheets and veins derived from the main mass are found to be intrusive in higher or lower levels of the strata in the same locality, as in the quarry at Victoria Park, the rock is generally seen to pass from its normal dark colour into different shades of light grey and greyish white, the alteration being evidently due to its contact with the sedimentary rock and to rapid cooling, especially along the lines of contact" *.

Mr. Young has kindly forwarded small specimens of the veins at Victoria Park, showing these variations, and I have examined sections made from those which appeared most typical, with the result that I find the dark, coarsely crystalline dolerite to consist of felspars which, from their extinction-angles, appear to be labradorite, but which are, for the most part, in too advanced a stage of alteration to admit of any optical determination. Olivine and ilmenite are also plentiful—the former mineral often showing alteration into serpentine or calcite, while the ilmenite has been, in great part, converted into leucoxene. Apatite is also plentiful in the form of slender hexagonal prisms. A considerable amount of green to brownish-green chlorite is also present, occasionally forming fringes, composed of fan-shaped aggregates of plates, around the walls of vesicles, the central portion of the vesicle being frequently filled with calcite. In addition to the minerals mentioned, the section shows a few small crystals of a dark-brown magnesian mica, and here and there a speck of pyrites.

Another specimen from the same locality, but of a totally different character from the preceding, is very fine-grained in texture, and of a pale bluish-grey, passing into a buff colour. In a section taken

* Trans. Geol. Soc. Glasgow, 1888.

from this specimen the chief constituents are decomposed felspar (labradorite ?) and olivine in irregularly shaped grains, sometimes containing fluid lacunæ with bubbles. These enclosures often take the form of negative crystals, whose outlines are rhombs or rhomboids, although they occasionally appear in approximately spherical or ellipsoidal forms. Limonite and pyrites are also present, and there is a small amount of interstitial glass.

A section taken from a still finer-grained chip from one of these veins, also of a pale grey or greyish-white tint, shows a confused felted mass of very small crystals, which, here and there, have a tendency to form little divergent or radiating groups. These, for the most part, seem to be minute decomposed felspars, while occasionally somewhat larger crystals of felspar may be seen, but they do not occur in sufficient number to give a micro-porphyritic character to the rock. In transmitted light the section shows a profusion of minute opaque specks, which, by surface-illumination, appear white, and are probably kaolin. Limonite and a few specks of pyrites are also present, together with a little calcite.

In the thinner parts of the section a certain amount of interstitial isotropic matter may be detected, and this is probably the original glassy basis. Its presence, however, cannot be satisfactorily made out in the thicker portions of the section, although it doubtless exists there, owing to the anisotropic bodies with which it is associated. There is, in fact, no evidence to prove that the vein solidified wholly as a glass, and I am inclined to think that it merely had a glassy basis or residuum, although the marginal portions were once quite vitreous.

This is the only point in which I differ from the opinions expressed by Messrs. Young and Corse Glen in the admirable paper already cited, and to which I am so largely indebted for information.

The devitrification both of the colourless and the coloured glassy bands forming the margins of these veins has been caused in great part by the development of globulites *, accompanied by a separation of what has apparently been titaniferous magnetite or ilmenite, now altered into leucoxene; but in the band (*c*) next to the shale the globulites are much more densely massed, and appear to be of a deeper colour, an appearance which is perhaps due in some degree to the fact that they are so massed, perfect opacity resulting in many places from this cause. It may be that some of the larger brownish granules are spessartine, as they closely resemble those seen in sections of the hone-stone or coticule from Viel Salm in Belgium, described by Prof. Renard †, and the occurrence of 0·14 per cent. of manganese protoxide in Mr. Holland's analysis of the rock tends to support this assumption. The main point of

* This devitrification seems to accord to some extent with that met with in a tachylyte described by Dr. P. N. Wenjukoff, "Sphärolith Tachylyt von Sichota Alin im Ussurgebiet," Bull. Soc. Belge de Géol. t. i. p. 367 (1887).

† "Mémoire sur la structure et la composition minéralogique du Coticule," Mém. Acad. R. Sci. Belg. t. xli. Bruxelles, 1877.

interest in these veins consists in what seems to be the reciprocal action of synchronous cooling and heating, which, if the foregoing interpretation of the microscopic phenomena be correct, must have taken place between the whin-vein and its adjacent walls of shale.

That there has been a somewhat rapid chilling of the whin is evident from the production of its once vitreons selvage, and it would appear that the heat needful for the retention of the whin in a state of fusion has been transferred to the shale, fusing the latter to a slight extent. The two vitreous bands (*b* and *c*) taken together seldom, indeed, attain a thickness of more than $\frac{1}{25}$ inch, so that a selvage of these small dimensions might easily be overlooked in the field by any but most careful observers.

An analysis of a specimen collected by Mr. Young from one of these narrow veins has kindly been made for me by my friend Mr. Philip Holland. The specimen showed the entire thickness of the whin-vein itself, after the removal of the shale with its adherent shale-glass selvage.

The following is the result of the analysis:—

White-Whin Vein, about one inch in breadth, Victoria Park, Whiteinch, near Glasgow. Sp. gr. 2·62.

SiO_2	=	45·240
Al_2O_3	=	17·080
Fe_2O_3	=	1·841
FeO	=	8·019
MnO	=	0·140
TiO_2	=	2·400
CaO	=	4·640
MgO	=	5·744
K_2O	=	0·127
Na_2O	=	5·315
P_2O_5	=	0·570
CO_2	=	2·980
Combined water	=	5·655
		99·751

P. Holland, F.C.S., F.I.C.,
Southport.

The microscopic examination, coupled with the chemical analysis, of this whin-vein indicates that its constituents are chiefly plagioclastic felspar (? labradorite), serpentine pseudomorphous after augite and olivine, calcite also pseudomorphous after augite and olivine, or forming amygdaloidal bodies.

In addition to these minerals there appears to be a small amount of garnet (probably spessartine?), represented by minute grains and occasionally well-formed crystals, a certain amount of leucoxene, resulting from the alteration of ilmenite and titaniferous

magnetite, and a very small quantity of sparsely distributed unaltered ilmenite. Finally, there is more or less interstitial glassy matter, now partially devitrified. The phosphoric acid is, no doubt, due to the presence of apatite; but the small dimensions of such crystals would easily cause them to be overlooked in a rock of such finely crystalline texture.

Discussion.

The Chairman (Prof. J. W. Judd), with reference to Mr. Rutley's suggestion as to the origin of the two layers of glassy rock, asked for further information. The veins were very small, and it was admitted that it was difficult to suppose they had produced fusion of the shale, when in the case of much larger dykes such fusion did not occur.

The Author stated that he had often been disappointed in his search for cases of fusion at the contacts of large intrusive veins and dykes, while, on the other hand, comparatively small veins had produced alteration of the adjacent rocks. He considered that the character of the rock must be taken into account. Absolute demonstration of the fusion of the shale was still wanting in the case described, but he believed that the conclusions given in the paper approximated to the truth.

39. Notes *on the* Bagshot Beds *and their* Stratigraphy.

By H. G. Lyons, Esq., R.E., F.G.S. (Read June 19, 1889.)

[Plate XXI.]

Since the publication in the Quarterly Journal of the Society (Q. J. G. S. xliii. p. 431) of a paper on the London Clay and Bagshot Beds of Aldershot, I have made a number of observations on these beds as they occur in the area between Aldershot and Ascot. These observations I would now place at the disposal of other workers, as I shall have no further opportunities of making use of them, and I would also shortly refer to the results to which they seem to me to lead.

In my previous paper, referred to above, I only discussed the beds at their southern outcrop over an area about 5 miles from E. to W. by 2 miles from N. to S., and showed that within this area the Bagshot and London-Clay strata remained of constant thickness and dipped at an angle of about $2\frac{1}{4}°$ northwards.

Over so small an area it was easy to obtain sections which would show what was required, and at the same time of a length short enough to avoid the necessity of any great exaggeration of the vertical scale in order to show the details. But now that the area under consideration is some 15 miles square, the difficulty becomes greater when a consideration of the effect upon this area of the Hog's Back monocline is attempted; however, as there is in the case of the 60 feet of strata grouped as Middle Bagshot a series of nearly constant thickness over the area, it occurred to me that if the attempt was made to *contour* the surface of this bed from the various known altitudes of the outcrops, from its positions in well-sections, and, in some cases, from its restored positions, where it has been removed by erosion, the result might very probably give the form into which the beds had been pushed by the different small flexures which there might be, and which were too slight to be seen in sections of any length. Of course it is not for a moment contended that this contouring can produce accurately the form of the surface; but it seems to me that it *may* be possible thus to group the different altitudes so as to show more clearly their relations to one another, and to accentuate rather more those slight and gradual rolls by which these beds have been affected and which, though insignificant in themselves, do, if unnoticed, increase the difficulties of correlating strata even in so small an area.

First, taking the country round Swinley Park, we have the pebble-bed at the top of the Middle Bagshot recorded at * Red Lodge at 300′ † O.D., observed on the road to the west at 290′, in Swinley

* Dr. Irving, Q. J. G. S. vol. xliv. p. 165.

† Heights shown thus (300′) are heights above Ordnance Datum; thicknesses have the word "feet" in full.

Park at 300′, and in the Deer-park at nearly 310′; it is also recorded * at Tower Hill, 300′, and Hagthorn Hill, 290′. Dr. Irving has also told me of the occurrence of this same bed at 300′ on Long Hill, the western extension of Goathurst Hill by Ascot; and we have a published section † of the deep well on Ascot Racecourse with 115 feet of Bagshot sand, almost, if not quite, all of which is Lower Bagshot. If we add to this 50 feet for the Middle Bagshots which have been removed, we get 300′ as the altitude for the pebble-bed. Then at Bracknell Station ‡, Easthampstead Church, the slope of Bill Hill, and in sections round Wellington College we get altitudes of 260′ and 265′.

Next, at the entrance to the Staff College at Camberley, on the Bagshot road, the pebble-bed is recorded at 260′ §, and as we go northward from here we have it at 165′ || in the well at the Albert Orphan Asylum. These two altitudes may seem to differ enormously, though situated so near together; but when the dip is calculated out it only gives a slope of a little over $\frac{1}{2}°$.

On the Railway between Bagshot and Ascot I have found the pebble-bed at 230′, 240′, and 255′, as shown on the map, and on Chobham Common as follows:—

Hill above Titlarks Farm	235′
Cross Road near Staples Hill	215′
Staples Hill	210′
Windlesham (near Mrs. Rothery's)	200′
—— Church	200′

At Barrow Hills the house is about 175′, and the well there (from particulars kindly furnished by Rev. A. Bramwell) passes through

	ft.
Clay (Middle Bagshot)	8
Fine Sand (Lower Bagshot)	37
Total	45

Adding 50 feet for the rest of the Middle Bagshot, we get 225′ for the restored altitude.

For St. Anne's Hill, Chertsey ¶, we have 220′ or 230′, and for St. George's Hill, Weybridge, a similar height, 230′.

Coming down the L. and S. W. main line we find it at 200′, by Whitsheet near Woking station, and at 185′ on the hill by The Hermitage near Woking Convict prison.

Now we come to a series of altitudes running due north from Worplesdon, 175′, by Dawson's Well 160′, and by Dawnay's Hill west of Woking Cemetery, about 160′.

* Q. J. G. S. vol. xliv. pp. 165, 166.
† Dr. Irving, *ibid.* vol. xliii. p. 387.
‡ Dr. Irving, Proc. Geol. Assoc. vol. ix. no. 6.
§ Dr. Irving, Q. J. G. S. vol. xli. p. 499.
|| Surv. Mem. vol. iv. p. 537.
¶ Mr. W. H. Hudleston, Q. J. G. S. vol. xliii. p. 443.

In Brookwood Stumps, just north of the Railway, in a well sunk at a new brick house, there was passed through

	ft.	
Yellow loam	10	Middle
Dark-green sharp sand with thick line of pebbles	7	Bagshot.
Total	17	

Level of well-mouth about 156′, thus giving about 160′ for the top of the Middle Bagshot, which crops out at 170′ at the south end and 175′ at the north end of Knaphill Common.

By the Gordon Boys' Home it crops out in a ditch below the sand-pits at the top of the hill at 165′, and at 160′ on the north side of the hill. East of this, pebble-gravel, overlying clayey Middle-Bagshot beds, occurs on Stanners Hill at 170′, and also at 200′ in the road east of Childown Hall.

Now Mr. Hudleston * gives the base of the Ongar-Hill Middle-Bagshot Clays as 100′ above O.D., so we may take 150′ as about the top of the Middle-Bagshot beds there originally, which is a fall of 15′ from the Royal Albert Asylum Well, and gives us the lowest point we have as yet got for these beds, and Row-Hill brickyard is about the same.

He also gives the base of the Woburn brickearths as 60′ above O.D., so if they should be basal Middle Bagshot the upper limit would hardly rise above 120′ above O.D.

Coming now to Hampshire (and omitting any recapitulation of altitudes of these beds given in my previous paper) †, at a well sunk at Farnborough Rectory, the Clay at the base of the Upper Bagshot was reached at a depth of 46 feet from the surface, which was at 250′ above O.D., so we here get 204′ for our upper limit.

Dr. Irving has also informed me of wells at Hawley Vicarage and Minley Manor, where the Middle-Bagshot strata had not been penetrated when a point 180′ above O.D. had been reached.

Here perhaps the well at Mychett Place, Frimley, should be mentioned, though I cannot produce any additional evidence in explanation of that furnished by Dr. Irving ‡; but taking into account the base of the Upper Bagshot at the Farnborough-Rectory well at 204′ O.D., and the fall of the beds as I show it in the contoured plan, I would suggest the reference of the first bed only, "White sand 53 feet," to the Upper Bagshot, the next 42 feet to the Middle Bagshot, then about 102 feet to the Lower Bagshot, and the remainder to the London Clay, though I know the assignment of so great a development of sandy beds to the London Clay has been strongly objected to.

If, now, with the aid of these data the area be contoured, the result is (not expecting any great topographical accuracy), I think, of some interest. We have a well-marked anticlinal, of which the axis points upon Windsor Castle (where, of course, the Chalk has been brought up through the Lower Tertiaries), and this anticlinal seems to pass through the Swinley and Wellington-College area, and

* Q. J. G. S. vol. xliii. p. 452. † *Ibid.* vol. xliii. p. 431.
‡ *Ibid.* vol. xli. p. 496.

without the limits of this map will, I think, run to Hazley Heath *, where the pebble-bed is about 290′, and to Shapely Heath, where it is about 300′.

The anticlinal shown through Hagthorn Hill, Swinley Park, and Cæsar's Camp, having a direction roughly S.W. and N.E., seems to me to explain the rises of the beds mentioned by Dr. Irving (Q. J. G. S. vol. xliv. p. 166),—viz. (1) the rise of the base of the Middle group as it passes eastwards along Nine-mile Ride; (2) the slight rise of the beds of the same horizon from Wokingham to Bracknell; (3) the dip to the westward of the clay and sand beds at Bracknell,—and to do so better than the N.W.–S.E. anticlinal, which he there postulates, and of which there is no evidence in Windlesham.

Next we have a well-marked synclinal starting by Minley and Hawley and running by the Royal Albert Asylum and Gordon Boys' Home, upon Ongar and Row Hills and Woburn Hill.

A curious point is the group of low levels round Pirbright Green. I believe they are for the most part correct; for in one case close to the railway-bridge north of Dawnay's Hill there is an Upper-Bagshot sand-pit at 156′, where Mr. Herries † obtained fossils. I have had 135′ O.D. given to me as the level of the top of the Middle Bagshot at the Manor House, Pirbright; and if this is correct the case of these grouped low levels is even more remarkable.

Then we have the anticlinal running on to St. George's Hill, Weybridge, and the northern slope of this will, it seems to me, give the fall of the surface of London Clay in a direction E.N.E. to W.S.W. as noted by Mr. Hudleston ‡; for from this paper of Mr. Hudleston's we have the base of the Bagshots 658 yards west of Walton Station at +85′ O.D., and $2\frac{1}{4}$ miles off, at the railway-bridge over the River Wey, it is at +30′ O.D.; so if we add 180′ to these we shall get 265′ O.D. and 210′ O.D. as the top of the Bagshot series originally, which helps to give us the direction of this anticlinal ridge.

Similarly the Swinley anticlinal roll will give the slight tilt to the westward which Dr. Irving notices §, and the southern side of it perhaps that dip to the S.E. he described under Finchampstead Church. No doubt more stratigraphical details would alter to some extent, and perhaps considerably, my delineation; but I believe the dominant features of it will be found to remain the same.

To the north-east of Chobham Common the Bagshot sands begin to disappear on the line of Chertsey and Egham; but it may be worth while to see what altitudes will be obtained by restoring a thickness of about 180 feet for the Middle and Lower Bagshots where they have been removed.

At Chertsey Brewery ‖ the London Clay is 386 feet thick, and has its upper surface at a level of 0′ O.D.

Next, taking the Holloway Sanatorium near Thorpe, about $1\frac{1}{2}$

* Messrs Gardner, Keeping, and Monckton, Q. J. G. S. vol. xliv. p. 613.

† *Tom. cit.* p. 612. ‡ *Ibid.* vol. xliii. p. 451. § *Ibid.* vol. xliv. p. 169.

‖ Mr. W. Whitaker, "Surrey Wells and their teaching," Croydon Micro. and Nat. Hist. Club, 1886.

mile N.W., we have 110 feet Lower Bagshot, and 329 feet of London Clay, well-mouth probably a little above 100′ O.D., which, again, brings the London-Clay surface to about 0′ O.D.; I can find no decisive evidence of these 110 feet being certainly Lower Bagshot, and part may be London-Clay beds. But about midway between these two points we have Saint Anne's Hill with the Middle Bagshot at least at an altitude of 220′; and taking 180 feet as given by Mr. Hudleston * for the combined thickness of the Middle and Lower Bagshot, we have the London-Clay surface at +40′ O.D., that is 40 feet at least above its position at Chertsey, a mile distant; and this line, if produced 2000 yards further, comes to Woburn Hill, where, if this slope has continued, we should expect to find the London-Clay surface at −45′ or −50′ O.D., and Mr. Hudleston † says that if the Woburn-Hill brickearth is to be basal Middle Bagshot, the London-Clay surface would be 60′ below O.D.

The greater part of Egham is at an altitude of 50′ O.D., and the London Clay was reached in the Staines-Waterworks well 23 feet below river-gravel, &c., and was penetrated 235 feet; so that if we restore the London Clay to the same thickness that it attains at Thorpe (330 feet), the surface of the London Clay will have risen to 122′ O.D., and the top of the Middle Bagshot to 302′.

And thus we get a fall in the London-Clay surface of 122 feet in a little over three miles from Egham to Chertsey, which gives 40′ per mile, or the same as we got between St. Anne's Hill and Chertsey; if we take the original thickness of the London Clay at 386 feet, as given by the Chertsey-Brewery well, the slope becomes 60 feet per mile.

Next I have attempted to map, as nearly as I could, the southern and eastern limits of the Upper Bagshots (Pl. XXI.) ‡.

It is at the most but an attempt to place the result of my work during the last two years at the disposal of others who may be interested in this district.

The boundary to the N.W. is not drawn, as I am not sufficiently well acquainted with the ground even to estimate its probable position, which, indeed, is all I claim for the eastern boundary. It will be seen at once that a much greater extent is claimed for the Upper Bagshot Sands than has been mapped by the Geological Survey, as since that was done fresh sections have constantly been available, and this area is also even larger than that proposed by Messrs. Gardner, Keeping, and Monckton §.

Commencing at Ash, where the pebble-bed is at 310′ O.D., and following the outcrop eastwards round the foot of the hills, it falls to 300′ due north of the head of East Wyke Lane and above the brickyard there. Thence it runs behind Normandy Park and again appears forming the surface of the ground at Dolleys Hill, 250′ O.D.; then gradually becoming undistinguishable as it is followed up Whitepatch Bottom, the boundary has to be drawn in from the line

* *Ibid.* vol. xliii. p. 452. † *Tom. cit.*

‡ Though the area tinted as Upper Bagshot includes the Blackwater Valley, this has only been left thus to avoid complicating the detail by drawing the boundaries of the river-deposits.

§ *Ibid.* vol. xliv. p. 609.

of springs and form of the ground passing just east of Rails Farm, where there is a sand-pit in the Upper Bagshot, skirting the hill above Duchies and that by Pirbright Lodge. Then it runs back to Furzehill Pond, and skirting, or possibly crossing and recrossing, the railway, takes in Dawnay's Hill just north of Pirbright Green, and then turns northwards just east of Brookwood Station, and follows the course of the brook up to Cowshot Farm, probably crossing it just above, and coming down the north side before turning back to the N.E. across Bisley Common. This point is of special interest, as this has been selected as the site for the National Rifle Association camp to replace Wimbledon.

The beds are dipping slowly northwards, and the clayey top of the Middle Bagshots ought, with the assistance of a system of French open drains, filled up with large stones, to drain this piece of ground successfully. Then again, as at the new well at Brookwood Stumps, the beds of greensand some 20 feet or 30 feet down in the Middle Bagshots would probably furnish an ample supply of water, besides that thrown out by springs at the base of the Upper-Bagshot sands, unless exception should be taken to the quality of this greensand water *; I may also mention that the surface of South Camp, Aldershot, is similar in structure though the dip is steeper, and that all the numerous shallow wells, about 20 feet deep, drawing their water from these Greensand beds have now been condemned for drinking-purposes. They are closed wells, and so have no chance of their water becoming purified by oxidation.

From this point the boundary is drawn from the ground and from sections and exposures at Donkey Town, Bisley, and Knaphill, till the Ascot railway branch is crossed, and the line bends to the west south of Swinley Park. From this point, for want of certain knowledge, the colouring has not been carried beyond the 300′ contour up to Broadmoor Bottom, and from there to the point 260′ O.D., where, as referred to above, the pebble-bed has been recorded.

West of South Camp, Aldershot, the boundary of the Upper Bagshot crosses the centre of the Long Valley, bends east of the Racecourse, and runs up into Beacon Hill, where the pebble-bed occurs at about 400′ O.D. west of the Waterworks.

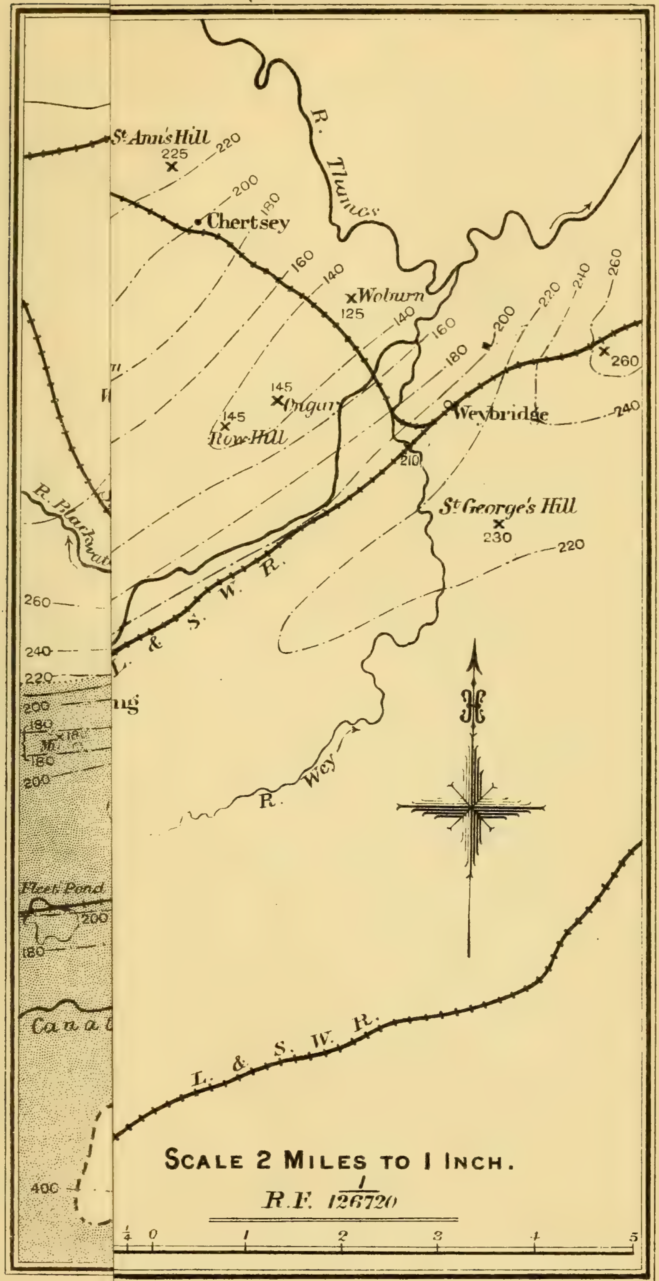
I do not know how much of the actual top of Cæsar's Camp, &c., should be coloured as Upper Bagshot, as the gravel-capping obscures all traces of the underlying sands, and where wells have been sunk it has been at the western end of the hill, near Heath House.

Cove Common and the part round Fleet I have mapped as Upper Bagshot, on the strength of numerous wells, about 18′ and 20′ in depth, which have been sunk, and various ditch-sections; and in no case have I been able to obtain any good evidence of any Middle-Bagshot beds, but only of normal Upper-Bagshot sand or the overlying drift sandy gravel. Round Bramshot Farm, between Fleet Pond and Hawley Pond, the soil becomes clayey, and on p. 313 of Prof. Prestwich's 'Geology,' vol. ii., *Cardita planicostata* is quoted as having been found at Hawley Pond, so we perhaps have here a Middle Bag-

* Dr. Irving, Geol. Mag. 1885, p. 17.

& Ascot.

Quart. Journ. Geol. Soc. Vol. XLV. Pl. XXI



Dangerfield, Lithographer, London. 18970.

Railways.

Roads.

hot.

Sketch Map of Country between Aldershot & Ascot.

Quart. Journ. Geol. Soc. Vol. XIV Pl XXI

Dangerfield, Lithographer London 18970

Contours shewing estimated height of base of U. Bagshot. 300′ Contour in unmapped area. Approximate boundary of U. Bagshot. Railways. Roads.

shot bed ; and if this is the case, the anticlinal shown in the map will be the more pronounced.

The line, Cricket Hill, Hill-Field Farm, Blackwater, where I have stopped the Upper Bagshot is an arbitrary one, as I have not sufficient information to continue it down to the junction with the Middle Bagshots which have been recorded at Yately, with an altitude of about 260′ O.D. for the upper limit.

Of the outliers there are two small ones on Knaphill Common and by Donkey Town, and one larger one on Chobham Common, which I have roughly mapped in, as well as a small one on Staples Hill.

I am only too well aware of the unfinished character of this paper, but as no opportunity for a more detailed and accurate revision of it can occur for at least several years, I have put together what facts I have in my possession so as to render them available for others.

EXPLANATION OF PLATE XXI.

Sketch Map of the Country between Aldershot and Ascot.
(Scale 2 miles to 1 inch.)

Discussion.

The Chairman (Prof. J. W. Judd) remarked on the value to be attached to detailed work carried on with excellent topographical maps.

Mr. Monckton noted that the line at which the Author had fixed the lower limit of the Upper Bagshot Beds practically coincided with that taken as the result of recent researches, and differed from that taken by the Geological Survey, causing a much wider extension of those beds. He considered it most desirable to take the well-marked pebble-bed as a dividing-plane. If the Upper Bagshot is to be extended beyond the limits of the Bracklesham Beds, he would like to learn the evidence for this. Sections at Bracknell, &c., were still the subject of controversy.

Mr. Herries preferred not to criticize buried contour-lines off-hand. He thought the evidence brought forward as to Hatch brickyard being in a syncline was of much interest, and perhaps the beds there might after all be Middle Bagshot.

Mr. Starkie Gardner, with the previous speakers, regretted that the Author was leaving the area.

The Author, in reply, congratulated himself that he had avoided those controversial matters on which he could not produce conclusive evidence, and so would not commit himself to a definite opinion about Bracknell. He thanked the Chairman for the way in which he had referred to his work.

40. CYSTECHINUS CRASSUS, *a new Species from the* RADIOLARIAN MARLS *of* BARBADOS, *and the* EVIDENCE IT AFFORDS *as to the* AGE *and* ORIGIN *of those* DEPOSITS. By J. W. GREGORY, Esq., F.G.S., F.Z.S., of the British Museum (Natural History). (Read June 19, 1889.)

THE most important addition made by the 'Challenger' to our knowledge of the living Echinoidea was unquestionably the discovery of those abyssal Spatangoids which are Ethmophract, Meridosternous, and Adete; it was the close resemblance of these to the Cretaceous Ananchytidæ that led to the well-known and oft-refuted generalization that we are still living in the age of the Chalk. The discovery of a new species of *Cystechinus*, one of the most typical of these genera, in the Radiolarian beds of Barbados is therefore of interest; and this is enhanced by the light it throws on the age and horizon of those well-known deposits.

Of the genus *Cystechinus* Prof. A. Agassiz has only given a comparative diagnosis; in the original description * he simply states that it has the general appearance of *Ananchytes*, the simple ambulacral system of the Pourtalesiadæ, and an actinostome less labiate than in that group. He points out that it serves, with the genera *Homolampus* and *Palæotropus*, as a transition from the Spatangidæ to the Nucleolidæ and Echinolampidæ.

In the 'Challenger' Report this notice has been somewhat expanded †. Here the Galeritic features of the subcentral actinostome and the position of the anal system, the Ananchytid apical disc, the simple pores, the rudimentary auricles, and the proportions of the coronal plates in the ambulacral and interambulacral areas are all noticed. But a positive diagnosis is necessary to the worker, as Prof. Duncan recently insisted when introducing his Revision of the Genera of Echinoidea to the Linnean Society; it may therefore be of use to summarize the characters of the genus. I must here express my thanks to Prof. Duncan for much kind advice; to F. A. Bather, Esq., for drawing the figures which illustrate the present paper; and to Prof. Jeffrey Bell for his assistance during my examination of the 'Challenger' specimens, without seeing which I should not have ventured on this diagnosis.

CYSTECHINUS, A. Ag., 1879.

Test attaining a considerable size. Shape normally oval, depressed or subconical above, and flat below, but variable, owing to the more or less flexible nature of the test. The plates vary in thickness from that of ordinary writing-paper to 1·5 mm.

* A. Agassiz, "Preliminary Report on the Echini of the Exploring Expedition of H.M.S. 'Challenger,'" Proc. Amer. Acad. vol. xiv. (Boston, 1879), pp. 207–8.

† A. Agassiz, "Report on the Echinoidea dredged by H.M.S. 'Challenger' during the years 1873–6," 'Challenger' Reports, Zool. vol. iii. No 1 (London, 1881), p. 148.

Apical system subcentral, slightly excentric posteriorly. Slightly produced and disjoint. Three or four genital pores. The position of the madreporite is variable; it is usually on the right antero-lateral basal, but it may have receded on to one of the adjoining intercalated perisomatic plates. These plates are two or more in number.

Ambulacra apetaloid. Ambulacral plates large and usually hexagonal, each perforated by a single pore, and either of the same number as the interambulacral plates or but slightly in excess.

Interambulacral plates normally hexagonal, broader than deep; horizontal sutures more or less curved. The plates of the postero-lateral interambulacra are the smallest. Caudal beak rudimentary or absent.

Epistroma. The whole test is ornamented with a fine granulation and scattered tubercles.

Actinostome central or subcentral; depressed, the edges raised into a rudimentary perignathic girdle. Actinal plates simple.

Periproct inframarginal, just below the ambitus.

No fascioles.

Three species of *Cystechinus* were found by the 'Challenger' Expedition, all of which came from very deep seas. *C. Wyvillii*, the type species, was dredged at depths varying from 1375 fathoms, off the Crozet Isles in the Antarctic Ocean (Stat. 146), down to 2160 fathoms off Juan Fernandez (Stat. 299), while it was met at intermediate depths at Stations 147 and 158 in the Antarctic Ocean, and at Stations 296 and 299 off the coast of Chile. *C. vesica* has been found to range from 1675 fathoms in the Antarctic Ocean at Station 153, to 2160 and 2225 fathoms at Stations 299 and 298, between Juan Fernandez and Valparaiso. *C. clypeatus*, the species which is probably the nearest ally of *C. crassus*, was found off Tristan da Cunha at Stations 133 and 334 and in the China Sea at Station 205, at depths of 1900, 1915, and 1050 fathoms respectively.

The bathymetrical range of the genus is therefore from 1050 to 2225 fathoms. Its geographical distribution is in the China Sea, in the Pacific off the S.W. coast of S. America, in the Atlantic near Tristan da Cunha, and in the Antarctic between the Cape and Australia. Its geological distribution is, with the exception of the species here described, limited to the present time.

CYSTECHINUS CRASSUS, n. sp. (Figs. 1–3, p. 643.)

Shape oval, depressed; posterior interradius flat. The flexibility of the test is slight, the plates are 1·5 mm. in thickness.

Ambulacra apetaloid. The plates are large and fairly uniform in size. In shape they are hexagons, which are usually nearly regular. They are of the same number as in the interradii, viz. 7 or 8 between apical disc and ambitus. The pore in each plate is central or subcentral, the excentricity being towards the abactinal side of each plate.

The plates are flat, without ridges, and covered by a minute granulation with a few irregularly scattered small tubercles.

Interradii. The plates are broader than those of the ambulacra; in shape they are hexagonal, but elongated. Horizontal sutures straight or very slightly curved. In thickness, number in vertical series, and distribution of epistroma they resemble the ambulacral plates. The postero-lateral plates are narrower than the antero-lateral pair.

Apical system central, small; the details of the arrangement as yet unknown, but it can only have been slightly disjoint or produced.

The actinal surface with the periproct &c. is not shown in the specimen.

Dimensions of type specimen.

				mm.
Length				150
Width				130
Thickness of plates				1·5
Ratio of depth to breadth of ambulacral plates; about				2 : 3
,,	,,	plates of interambulacrum	No. 1; about	4 : 5
,,	,,	,,	No. 3; about	3 : 5

Locality and Stratigraphical Position. The specimen (B.M. No. E 318) was obtained by Thos. D. Hill, Esq., in a drab Radiolarian marl at a depth of 166 feet on the Haynesfield Estate, Barbados. The specimen was presented to the British Museum (Nat. Hist.) by G. E. Thomas, Esq., of Haynesfield.

The age of the marl is probably Pleistocene or late Pliocene, but possibly Miocene, as will be subsequently discussed.

Affinities of Cystechinus crassus.—The specimen is unfortunately in a very imperfect state of preservation, as the actinal side is not shown, and the structure of the apical system can only be inferred. Even on the abactinal side many of the plates have been lost, though they have left clear impressions of the sutural lines and casts of the pores. Nevertheless none of the 'Challenger' collections of *Cystechinus* in the Natural History Museum are more perfect, except a couple of very young specimens of *C. Wyvillii.* The specimen is in better perservation than the collection of scattered plates that forms the type of *C. clypeatus*; a palæontologist need not therefore be afraid to deal with the materials when the zoologists have not hesitated to use worse.

The specimen was originally identified as *Calymne*, no doubt largely owing to the fact that Sir Wyville Thomson had placed * in that genus the fragments of a form found at Tristan da Cunha, with which this species is allied, and on which A. Agassiz has subsequently founded the species *Cystechinus clypeatus.* From *Calymne*, however, it is distinguished by the structure of the apical system, which is here less produced and disjoint, has fewer intercalated perisomatic plates, and the basals more uniform; the plates of the ambulacra, moreover, are less uniform and regular in *Calymne* than in *Cystechi-*

* Sir Wyville Thomson, "The Voyage of the 'Challenger.' The Atlantic," vol. i. (London, 1877), p. 399.

Fig. 1.—Cystechinus crassus, sp. n., *from the Radiolarian Marls, Haynesfield, Barbados: abactinal surface.* $\frac{2}{3}$ nat. size. (The plates shaded are those preserved in the specimen.)

Fig. 2.—*The same, from the right side.*

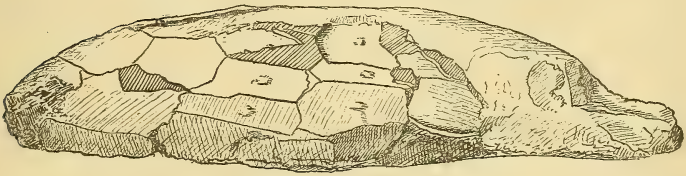
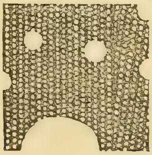


Fig. 3.—*The same, ornamentation of Plates.*



1 millim. of the plate marked by an asterisk in fig. 1, enlarged 20 diameters. The white dots represent matrix filling up depressions in the plate.

nus crassus. In general shape, so far as the fragments of *Calymne* enable any comparison to be instituted, it more resembles *Cystechinus.* The other characters of *Calymne,* viz. the subanal fasciole and pronounced caudal beak, are useless for comparison, owing to our ignorance of the structure of the actinal surface of the fossil.

Cystechinus crassus differs from the other three species of the genus in the greater thickness of the plates of the test. In most cases these are of extreme tenuity, and the test must have been very flexible. The thickness of those plates of *C. crassus* that can be measured is 1·5 mm. Owing to this flexibility of the tests, shape can only be used for specific distinctions within certain narrow limits. In other respects *C. crassus* differs from *C. vesica* in that in the latter the number of the ambulacral plates is greater than that of the interambulacral, and there are differences in the shape of the plates. From *C. Wyvillii* the new species differs in that (1) the plates lack the radiating ridges that ornament that species (see, *e. g.*, Chall. Rep. vol. iii. pl. xxix. *b*, fig. 9): (2) there are fewer plates between the apical system and the ambitus; they are 7 or 8 in number in *C. crassus* and 10 or 11 in *C. Wyvillii*: (3) the plates are deeper in proportion to their width; thus the plates of the posterior ambulacra of *C. crassus* are almost regular hexagons, whereas those of the largest specimens of *C. Wyvillii* are nearly twice as wide as deep: (4) the horizontal sutures are less sinuous in this species: (5) the ambulacral plates of the same area are more uniform in size and more regular in shape; thus in following down the vertical series in an ambulacrum of *C. Wyvillii*, long, somewhat narrow sinuous plates may be seen between hexagonal and pentagonal plates. The new species is probably most closely allied to *C. clypeatus*, and especially to the variety represented by those specimens found between Manilla and Hongkong; these, however, are so fragmentary that no precise comparison can be made between them and *C. crassus.* From the type specimen of *C. clypeatus,* the new species is clearly distinguished (1) by the smallness of the apical system, (2) the greater number of the ambulacral plates, (3) the straighter horizontal margins of the plates. If therefore the Philippine fragments belong to the same species as the fossil from Barbados they must be removed from *C. clypeatus.* It is quite possible that the closer affinity of the Manilla and Barbados specimens is only a superficial resemblance due to the fact that they are both from a less depth than the others; the discovery of more perfect specimens of the Philippine species might ally it with either species, or prove its distinctness from both.

Resemblances of the Plates to those of the Palæechinoidea.—When comparing this species with its allies, one cannot but be struck by the remarkable resemblances between their plates and those of the Palæechinoidea, which are especially obvious in this thick-plated form. Almost the whole of the Echinoidea intervene between the Exocyclic Spatangoidea and the Endocyclic Palæechinoidea, and the plates of the only Palæozoic Exocyclica (*Echinocystis* and *Palæodiscus*) are too imperfectly known for useful comparison. Nevertheless the similarity in the structure of the test is most surprising. In both

the tests are flexible, composed of hexagonal plates, provided with apetaloid ambulacra, with a single pore in each plate of the ambulucra, and an epistroma of minute granulation with small sparsely scattered tubercles exactly like those of some of the Perischoechinidæ, such as *Palæchinus*. This is not the time to discuss the meaning of these resemblances, but they are too striking to be wholly ignored.

As *Cystechinus crassus* adds but little to our knowledge of the morphology of the genus, the chief interest of the specimen depends on the place of its occurrence and on the light it throws upon the age and origin of the classical Radiolarian deposits of Barbados and some questions connected therewith.

The Island of Barbados is composed of three distinct sets of beds—the Scotland formation; the Radiolarian deposits; and the Coralline limestone. The term Scotland formation was applied by Sir R. Schomburgk * to the beds in the island below the Coralline limestone, and including the Radiolarian deposits; but as we are informed by Mr. Jukes-Browne and Prof. Harrison † that they will shortly be able to prove that the latter are quite distinct and overlie the other unconformably, the term may be restricted to the lower beds. As such it would include a group of strata which Sir R. Schomburgk describes ‡ as composed "of siliceous sandstone, intermixed with ferruginous matter, calcareous sandstones, siliceous limestones, different kinds of clay, selenite, and earthy marls, frequently containing fragments of pumice, strata of volcanic ashes, seams of bitumen, and springs of petroleum (Barbados tar)." The rocks of this formation appear to form the whole substructure of the island, though they only appear through the capping of coral limestone over one seventh of the total area. Their age has, unfortunately, never been conclusively settled. Three new species were found in these beds by Sir R. Schomburgk and described by Forbes §; the species were as follows:—

(1) *Scalaria Ehrenbergi*, Fbs., found in the siliceous limestone of Bissex hill. Though Forbes remarked the close resemblance of this specimen to the *S. crassilabrum*, Sow., of the Philippines and Central America, he considered it as probably of Miocene age.

(2) *Nucula Packeri*, Fbs. Allied to some tropical, subtropical, and Crag forms.

(3) *Nucula Schomburgki*, Fbs. A species attributed to a small section of the genus, which ranges from the Cretaceous upwards, but of which the nearest ally is probably *Nucula Cobboldiæ* of the Crag.

So far as I am aware this is the only direct palæontological evidence, except for the Radiolaria, as to the age of the beds, and it was upon this that Forbes based his suggestion that they were Miocene ||.

* Sir Rob. H. Schomburgk, 'The History of Barbadoes' (London, 1847), p. 534.

† J. B. Harrison and A. J. Jukes-Browne, "Origin of the Radiolarian Earth of Barbadoes," Nature, vol. xxxix. 14th Feb. 1889, p. 367.

‡ Schomburgk, *op. cit.* p. 534. § Schomburgk, *op. cit.* pp. 565–7.

|| Schomburgk, *op. cit.* pp. 556–565, 566.

In the case of at least the two *Nuculæ* the evidence would be quite as strong in support of their Pliocene age. Mr. Jukes-Browne and Prof. Harrison do not definitely accept Forbes's conclusion, and only speak * of the beds as early Tertiary; but the evidence of the two species of *Nucula*, whatever it is worth, would make the beds later rather than earlier.

The Radiolarian deposits include a somewhat variable series of marls, chalk, and ooze, which sometimes amounts to about 2000 feet in thickness. They occur in many parts of the island, and rise at Hillaby Mt. to a height of about 1145 feet. According to Sir R. Schomburgk they are interstratified between beds of the Scotland formation and are accordingly of the same age, a conclusion hitherto almost universally accepted. We now learn, however, from the letters of Mr. Jukes-Browne and Prof. Harrison already quoted, that the formations are quite distinct, and that the Radiolarian deposits rest unconformably on the Scotland rocks, between the latter and the Coralline limestone.

The Coralline limestone is the most recent of the three divisions, and extends over nearly six sevenths of the island, though it apparently does not exceed from 150 to 200 feet in thickness; the limestone contains a good many shells, Echinoderm spines, &c., of which Schomburgk publishes † a list of 59 species; there is also a collection in the Society's Museum; the fossils are all of living species, and there can be no doubt of the Pleistocene age of the rock.

The specimen of *Cystechinus crassus* was obtained on the Haynesfield Estate, at a depth of 166 feet below the surface. The estate is situated on the Coralline limestone, and the house is at an elevation of 707 feet above the sea. The Coralline limestone in this part of the island is from 150 to 200 feet in thickness, and the wells, Mr. Jukes-Browne informs me, rarely penetrate through the limestone, as they usually find water near its base. The fossil may, however, have been derived from a well deeper than usual, or from a boring, and thus have been obtained from the underlying Radiolarian marl. That it did come from the Radiolarian marl, is clearly proved by the matrix; and though it is very unlike the white Barbados chalk, which is the commonest variety in collections, it agrees very closely with a specimen in the Society's Museum (Barbados coll. M S. No. 12). By washing the matrix an abundance of Radiolaria of the typical form of the deposits can be obtained, though not so perfect as those from the white chalk; this suggested the possibility of the rock being composed of materials accumulated by denudation of the Radiolarian ooze, and thus being of the age of the Coralline limestone. A couple of thin sections have been prepared to test this point, and they quite set the question at rest; there is no trace of any coral matter, and the clay is seen to be charged with Radiolarian tests, spicules and fragments, spicules of *Actinolithus*, *Geodites*, &c., scattered through a fine argillaceous matrix. Dr. Hinde has kindly examined

* A. J. Jukes-Browne and J. B. Harrison, "Tertiary Chalk in Barbados," Nature, vol. xxxix. 25th April, 1889, p. 607.

† Schomburgk, *op. cit.* pp. 562–5.

the slides and fully endorses the view that the rock belongs to the Radiolarian deposits, while he has further shown me some slides of the Barbados Radiolarian earth in his own collection, which prove their identity.

The fossil having therefore come from the Radiolarian deposits, it is necessary for the purpose of this paper to consider the evidence for the age of the beds, and to see what light this fossil throws upon the question. It may be taken that the Radiolarian deposits are of later date than and not interstratified with the Scotland formation, and the age is therefore between that of the latter and that of the Coral limestone. No definite answer can be given as to the age of the Scotland formation ; the evidence of the three species of Mollusca is certainly inadequate to prove their supposed Miocene age, especially as the species are admittedly close allies of Pliocene forms. With the Radiolaria the case is no better, as the writers on this group (Butschli *, von Zittel †, and others) have accepted Schomburgk's and Forbes's opinion, and as both the premisses of this are disputed, it is hardly safe to accept the conclusion. Ehrenberg, when abandoning ‡ his old view of the Mesozoic age of the Radiolarian deposits in deference to Forbes's opinion, referred to the difficulty of separating the lower Tertiary beds from the Chalk, although he thought this would be accomplished by further microscopical research. He thus showed that he recognized that the two sets of deposits were quite distinct.

Häckel has, however, instituted a comparison between the Radiolarian fauna of the Barbadian deposits and that of the recent seas, and finding that only about 25 per cent. are common to the two, has supported the Miocene age with a more weighty argument §. But neither is this at all conclusive ; the living Radiolaria have hardly been sufficiently well worked to enable any such proportion to be of the value that would belong to one of the better-known groups, and a closer search would doubtless considerably increase the number of forms common to the faunas. The value of the species of Radiolaria is very doubtful, and, moreover, Radiolaria are probably of no more value than Foraminifera in the correlation of deposits. Echinoids, on the other hand, have always been regarded as of special value as time guides, and the evidence of one Echinoid is worth that of many Radiolaria. *Cystechinus crassus* is unquestionably closely allied to the living species of the same genus, and although deep-sea forms may be very conservative, it certainly seems to show that the beds are of comparatively recent date, either Pliocene or Pleistocene.

* O. Butschli, "Protozoa," Bronn's Klassen und Ordnungen des Thierreichs, Bd. i. 1882, pp. 476–8.

† K. von Zittel, Paläozoologie, Bd. i. (München, 1879), p. 118.

‡ Ehrenberg, "Fortzetzung der mikrogeologischen Studien als Gesammt-Uebersicht der mikroskopischen Paläontologie gleichartig analysirter Gebirgsarten der Erde, mit specieller Rücksicht auf den Polycystinen-Mergel von Barbados," Abh. d. k. Akad. Wissensch. Berlin, 1875 (1876), p. 114.

§ E. Häckel, "Report on the Radiolaria collected by H.M.S. 'Challenger' during the years 1873–6," 'Challenger' Reports, Zool. vol. xviii. pt. 1 (London, 1887), p. clxxv.

Its occurrence below the base of the Coral limestone is, moreover, quite in harmony with this view. The evidence of the Mollusca of the Coral limestone shows that this rock is of Pleistocene age; if therefore we accept the conclusion * of Mr. Jukes-Browne and Prof. Harrison that the deposit is part of a raised ocean-bed, then it is not improbable that the higher beds of the Radiolarian series did not much precede the foundation of the coral-reefs that grew over them on their elevation into a shallow sea.

But in addition to the question of age, *Cystechinus crassus* throws considerable light upon the origin of the Radiolarian deposits and the depth at which they were formed. Messrs. Jukes-Browne and Harrison have recently adduced the Radiolarian beds as an instance of the elevation of deep-sea deposits above the sea, in reply to the statement of the advocates of the permanence of oceans and continents that such has never occurred. This Radiolarian ooze, according to the authors named †, gives evidence of a complete interchange of continental and oceanic conditions in Tertiary times; for the underlying sandstones and shales imply the close proximity of a continent during their formation, while the chalky series proves the subsequent conversion of this sea into an oceanic area. Häckel, moreover, says ‡ that the Barbadian deposits are to be regarded as pure Radiolarian ooze in the fossil condition, and limits the term Radiolarian ooze to the deposits formed at great depths; and he further points out § that the fossil Radiolaria of Barbados are most nearly allied to those of the most abyssal fauna, in which conclusion he is supported by the observations of Dr. Teuscher ‖.

The discovery of a species of *Cystechinus* in these deposits is therefore of interest as confirmatory of these opinions: *Cystechinus* is one of the most typical of deep-sea Echinoids; thus, for example, Neumayr quotes it with a few other genera as never found above the 1000-fathom line. The case would have been quite as strong had the species belonged to *Calymne*, as at first thought, rather than *Cystechinus*, as the former genus has only been found at a depth of 2650 fathoms. Prof. A. Agassiz attributes ¶ to *Calymne* a range of 620-2650 fathoms; but this is probably a misprint, as it was only once met with, and the locality, it may be mentioned, was not Fayal in the Azores, as stated throughout the 'Challenger' Echinoid Report, but at Station 53, on the voyage between Halifax and Bermuda. Sir Wyville Thomson, who founded the genus and species, has fully described the discovery of the specimens **, and his account is confirmed in the official narrative of the expedition ††.

* Jukes-Browne and Harrison, *op. cit.* p. 367.

† Jukes-Browne and Harrison, *op. cit.* p. 607.

‡ E. Häckel, *op. cit.* pp. clvi, clvii.

§ E. Häckel, "Entwurf eines Radiolarien-Systems auf Grund von Studien der Challenger-Radiolarien," Jena. Zeitschr. f. Naturwiss. xv. 1881, p. 422.

‖ E. Häckel, Chall. Rep. vol. xviii. pt. 1, p. clxxv.

¶ A. Agassiz, *op. cit.* p. 218.

** Wyv. Thomson, *op. cit.* p. 206.

†† "Report on the Scientific Results of the Voyage of H.M.S. 'Challenger' during the years 1873-6." Narrative, vol. i. pt. i. (London, 1885), p. 161.

But as the depths assigned to *Cystechinus* rest solely on the records of the 'Challenger,' and as the depths given by this expedition have been seriously questioned, it becomes necessary to consider how far dependence can be placed upon them. In the preface to the narrative of the 'Challenger' expedition the following statement is made*:—"With respect to the depths assigned to the zoological specimens, it may be well to state that the naturalists of the expedition have simply recorded the greatest depth to which the dredge or trawl was believed to have descended at each station. It will be evident that the instrument may have been occasionally dragged into slightly deeper or shallower water than was recorded by the sounding-line, and, what is of greater consequence, the trawl or dredge may have caught animals while sinking through the water or being hauled up again. In the great majority of cases there is little difficulty in deciding which animals were dredged from the bottom and which were caught by the instrument in surface or subsurface waters. With some fish, Crustaceans, Medusæ, and other groups, however, there is considerable difficulty; in these cases the organization is often a guide, and the specialist who has made a careful study of the group to which the species belongs is best able to form an opinion as to the depth at which the specimens were probably captured. These circumstances should therefore always be borne in mind when the depths at which animals have lived are being discussed, and only after careful consideration should it be inferred that they were procured at the depths assigned to them in the lists." This warning has been repeated † equally emphatically in a review in the 'Athenæum,' which contains strong internal evidence of the authorship of Prof. Moseley; the validity of the conclusions based by Mr. J. J. Quelch on the recorded depths of some reef-corals from below the 30-fathom line is absolutely denied, as in the cases in question "the dredge ranged while down from 30 fathoms or 1 fathom or 10 fathoms to greater depths, but there is no proof at all that it did not pick up the corals at the least depth encountered." But with Echinoids, and especially with edentulate Spatangoids, which must have lived on or burrowing through the ooze, there can be no doubt that they were derived from the bottom, though the pumice, palm fruits, leaves, &c. associated with them at Station 205 were probably picked up near the surface. Very few particulars, however, have been given by the 'Challenger' reporters as to the range of depth crossed during the day's run; but had this been serious it could hardly have escaped notice. The only case in which any serious discrepancy might have occurred is that off the Philippine Islands; and it is not likely there, as the dredge was dropped in 1050 fathoms, and the depth had increased to 2100 fathoms at the next Station.

Cystechinus crassus was probably an inhabitant of a less depth than either of the previously described species of the genus, as is indicated by the greater thickness of the plates of the test. Lovén

* *Ibid.* vol. i. pt. i. pp. xi, xii.
† Athenæum, No. 3116, July 16, 1887, p. 87.

has, however, shown * that the abyssal genera of the present day, such as *Argopatagus*, *Palæotropus*, *Urechinus*, *Cystechinus*, and *Calymne*, are apetalous, while the littoral genera of the Clypeastroidea and Petalosticha usually have petaloid ambulacra, and that, moreover, the same peculiarity may be noticed within the limits of a single genus; thus in *Schizaster* the deep-sea species are less petaloid than the littoral. This feature Lovén attributes to the nature of the gases of the abyssal waters. *Cystechinus crassus* is apetalous, and as we might have expected some variation in this point in the ambulacra had the species been a shallow-water form, we may fairly conclude that it was a dweller in the deep seas.

The imperfect preservation of this, the only fossil specimen of its family, is to be deplored, the more so since their abyssal habitat is as unfavourable to their being found by the palæontologist as the fragility of the test in recent species is to their preservation by the zoologist. A more thorough search in the Radiolarian deposits of Barbados may, however, bring to light further material. Nevertheless the foregoing description, despite its inevitable imperfection, appears justified not only by the intrinsic interest of the genus, nor merely by the unique position of the specimen as the sole extinct representative of its group, but by the evidence of this fossil as to the age and origin of the Barbadian deposits—an evidence which, as herein suggested, is not without its bearing on some broader questions of geological speculation.

Discussion.

The Chairman (Prof. J. W. Judd) congratulated the Author on the very clear way in which he had laid his facts and inferences before the Society.

He considered that if it could be demonstrated that these deposits were so late as the Author supposed, and that the material was actually laid down in such deep seas, it afforded strong proofs of striking movements in comparatively recent times.

The Author stated that these Barbados rocks were much contorted, showing that differential movements had taken place in comparatively modern times.

* S. Lovén, "On *Pourtalesia*, a Genus of Echinoidea," Kongl. Svenska Vetensk. Akad. Handl. new ser. xix. No. 7, 1883, p. 95.

41. *The* Descent *of* Sonninia *and* Hammatoceras. By S. S. Buckman, F.G.S. (Read June 19, 1889.)

[Plate XXII.]

Part I.—*Sonninia.*

The genus *Sonninia* was founded by Bayle * to take the place of his *Waagenia*, a name which had been just previously used; and the type species was the same, *Sonninia* (non *Waagenia*) *propinquans* †, Bayle.

The species which are closely allied to *Sonninia propinquans* are *Sonninia Sowerbyi* (Miller), *Sonn. Browni* (Sowerby), *Sonn. adicra* (Waagen), *Sonn. mesacantha* (Waagen), *Sonn. fissilobata* (Waag.), and, with the exception of the last, which was referred to *Amaltheus* ‡, these species were located by Waagen in his genus *Harpoceras*. In this he was followed by Wright and many other authors; but Neumayr § relegated them, or most of them, to Hyatt's genus *Hammatoceras*, and has been followed herein by Zittel || and others. Haug ¶ makes two divisions of these species:—1st, Gruppe des *Hamm. Sowerbyi*; 2nd, Gruppe des *Hamm. Ogerieni* (*Sonninia*, Bayle); and his opinion is that the Inferior-Oolite species, *Amm. propinquans*, *Amm. patella*, &c., are the direct descendants of the Liassic species, *Amm. Ogerieni*, *Amm. navis*, &c.

Thus far the history of the species embraced by the genus *Sonninia*. My present object is to show their probable descent, and by that means their correct relationship in a genealogical sense to various genera.

The supposition that *Sonninia propinquans* was descended from *Haugia Ogerieni* takes no account of such a species as *Sonninia acanthodes*, n. sp. Whence has *S. acanthodes* derived its ventral furrows? and how, unless we suppose a case of atavism, has it acquired its circular (changing to quadrate) evolute whorls? and, instead of being almost smooth as we should expect the next descendant of *Haugia Ogerieni* to be, how has it acquired its large spines and coarse ribs? At the same time its suture-line is more highly ornamented than that of *Haugia Ogerieni*, which, had it been a case of atavism, would, I fancy, hardly be the case. It may, however, be urged that if the quadrate-whorled evolute *S. acan-*

* Bull. Soc. Géol. France, sér. 3, vol. vii. p. 92 (1878–79).

† Explic. Carte géol. France; Explan. of plate lxxxiv.

‡ "Die Formenreihe *Amm. subradiatus*," Geogn. Pal. Beiträge, Bd. ii. Heft ii. p. 248, footnote.

§ "Ueber unvermittelt auftretende Cephalopoden-typen," Jahrbuch k. k. geol. Reichsanstalt, Bd. xxviii. 1878.

|| Handbuch der Paläontologie, "Cephalopoden," p. 461.

¶ "Beitr. Monogr. Harp.," Neues Jahrbuch für Mineral. &c., Beil.-Bd. iii. p. 654 *et seq.*

thodes has not sprung from the compressed involute *Haugia Ogerieni*, yet that the same parent produced both forms.

At first sight this is probable, and would account for the ventral furrows of *Sonninia*; but then the peculiar inner whorls of *Sonninia*, with their flat, broad, ventral area, and coronet of spines, ought to bear some resemblance to the inner whorls of *Haugia Ogerieni*, but they do not bear the slightest. The inner whorls of *Haugia Ogerieni* are smooth; while the knobs—not spines—which appear, rise on the inner margin, and ribs proceed from them across a rather flat lateral area.

The supposition that *Sonninia propinquans* and *S. Sowerbyi* are descended from *Hammatoceras* is founded on the peculiar resemblance between *Sonninia Sowerbyi* and *Hammatoceras subinsigne*. Looking at the matter from a chronological point of view, the descent of *Sonninia* from *Hammatoceras* is very suggestive. The latter dies out in the *Concavum*-zone—that is, just at the time when the former first appears; but here, again, *Sonninia acanthodes* and the species like it are stumbling-blocks.

Practically speaking, I have not found any sign of a similar sulcated ventral area among the young or adults of *Hammatoceras*. Another small, but none the less important, point is that the ribs of *Sonninia* have a prominent forward sweep on the ventral area; but the ribs of *Hammatoceras* meet the carina almost at right angles—in fact they generally appear as if the carina had cut cleanly through them. However, the chief point is the suture-line. The characteristics of the suture-line of *Hammatoceras* (Pl. XXII. figs. 16–20) are the narrowness and depth of the siphonal saddle, and the oblique direction of the inner lobes. If *Sonninia* were descended from *Hammatoceras* it ought to show some of these characters, or some change from them which could be explained; but it shows (figs. 6–10) a shallower and broader siphonal saddle, and its inner lobes are less developed and more nearly in a straight line with the others. We might reasonably expect to find a suture-line with straighter inner lobes in *Hammatocerata* which had acquired, like *H. amaltheiforme* (Vacek), a wider lateral area, although, as it happens, we do not; but *Sonninia acanthodes* is, practically, less involute than *Hamm. insigne*, and especially than *H. subinsigne*, and has a narrower lateral area in which to accommodate its lobes. What reason is there for the suture-line to have so changed from *Hamm. subinsigne* or *Sieboldi* to *Sonninia Sowerbyi*, while the outward shape has changed so little?

If, however, we turn our attention to the genera *Pleuroceras* and *Amaltheus*, we shall find ourselves able to trace most of the distinctive characters of *Sonninia* in species of those genera; and we shall also be able to discover a definite analogy in the development of *Sonninia* and *Amaltheus*. Further we shall see a great resemblance between the most developed forms of *Sonninia* and *Amaltheus*, and between the inner whorls of the less-developed *Sonniniæ* and the inner whorls of *Pleuroceras*.

Amaltheus and *Pleuroceras* are undoubtedly descended from one common ancestor. Where that ancestor may be I cannot undertake

to say; but the form of the ancestor of these two genera may be gathered if we imagine a very considerable enlargement of the inner whorls of *Amaltheus* (fig. 25 is enlarged only about 4 times).

This specimen may be described as possessed of a simple coronet of spines, and, practically, an uncarinate ventral area. Both *Pleuroceras* and *Amaltheus* agree in having similar inner whorls which develop as follows:—

Pleur. spinatum, when broken up, shows the commencement of the keel at 2 lines, with a broad ventral area and a coronet of spines up to $4\frac{1}{2}$ lines; after that a flattened side and indications of a second row of spines; sulcations on each side of a crenulated carina not before 11 lines.

Pleuroceras hawskerense shows single spines up to a diameter of 6 lines; after that a second row of spines accompanied by a more flattened side.

Pleur. pseudocostatum shows, when broken up, a ventral area without carina, a lateral area with folds or small knobs, and an aperture somewhat broad ventrally at $2\frac{1}{2}$ lines; the folds or knobs developing into ribs with a spine towards the outer end, the faintest suspicion of carina, the sides more flattened at 5 lines; a noticeable carina, prominent ribs with a forward ventral sweep at 8 lines; a crenulated carina and sulcated ventral area not before 14 lines.

Amaltheus margaritatus exhibits an uncarinate ventral area and a coronet of single spines at 2 lines diameter; while before it reaches 5 lines the sides are much compressed.

We see from the above that a form with uncarinate ventral area and a coronet of spines is common to the early stages of *Pleuroceras* and *Amaltheus*. We can trace the development of the various branches therefrom as follow:—The *Amaltheus*-branch, which adds first a crenulated carina and a slightly flattened whorl, but retains the spines—such is *Amaltheus gloriosus*, Hyatt. From this species, through *Amal. turgidus* and *Amal. margaritatus* to *Amal. præstabilis* on one side, and to *Amal. Engelhardti* on the other, is an exact course of development—the descendants ever inheriting their parents' characteristics at an earlier age *. The tendency of this development is to flatten and broaden the whorl, to increase the involution, and to supersede the spines.

The *Pleuroceras*-branch must be divided into two:—1st. The *Pleur.-pseudocostatum*-group, in which the side becomes flattened, and produces a rib inside the spine, while the ventral area remains uncarinate for a time, and in which the ventral sulcations, after the advent of the carina, are never so prominent; 2nd. The *P. hawsker-*

* When I wrote (Monogr. Inf. Ool. Amm., Pal. Soc. 1888) my remarks concerning the changes observable during the evolution of the Hildoceratidæ, and showed how these followed, as it were, certain definite rules, I was not acquainted with anything Prof. Hyatt had written upon the evolution of other families; and this accounts for my not having made any mention of his work. Although regretting that I was not previously acquainted with such valuable work, yet I cannot but be agreeably pleased to find that my observations upon the mode of evolution of the Hildoceratidæ agree so exactly with what he has recorded concerning other families.

ense- and *P. spinatum*-group, in which the carina commences while the spines remain single, and in which the spine develops as the side flattens, first, into a rib and spine, and, lastly, into a rib and two spines.

It is from the earlier stage of this last group that I imagine the *Sonninia*-branch to have sprung—a stage when the coronet of single spines was present, as well as the carina. I imagine that the *Sonninia*-ancestor persisted in the coronet of single spines and even exaggerated the character; and then that it added sulci each side of the carina in the same manner as *Pleuroceras* had done at a later period of *its* life. In fact the *Sonninia*-branch accompanied *Pleuroceras* until the latter fell away and flattened its side and developed its single spine into a rib and two spines. Then the *Sonninia*-branch remained constant to the old shape, and apparently it retained this shape for a long period. Ultimately it narrowed its ventral area, decreased the sulcations, flattened its side, and, in old age, replaced the large spines by very coarse ribs. It is in this state that we first meet with it as *Sonninia acanthodes.*

It is extraordinary that we are acquainted with no species of *Sonninia* before the *Concavum*-zone, consequently my theory concerning its descent must be entirely derived from a study of the inner whorls of *Sonninia acanthodes.* I will briefly trace the life-history of a specimen as shown by its inner whorls :—

1. Diameter $\frac{3}{4}$ line. A smooth, globose, rather involute, thick shell, in form not unlike *Nannites fugax* (Zittel, 'Handbuch Paläont.' "Ceph." p. 446), but with a larger umbilicus (fig. 22; compare also fig. 24). Suture simple, Goniatite style (fig. 6).

2. Diameter 1 line. Ventral area arched, with carina and two small sulci; coronet of spines first commencing (fig. 23, *a*, *b*).

3. Diameter 2 lines. Ventral area more flattened, with carina and two sulci (fig. 23, *c*).

4. Diameter $4\frac{1}{2}$ lines. Ventral area becoming more arched, sulci present, but not so conspicuous proportionally *; carina hollow; ribs with forward inclination from spines towards sulci.

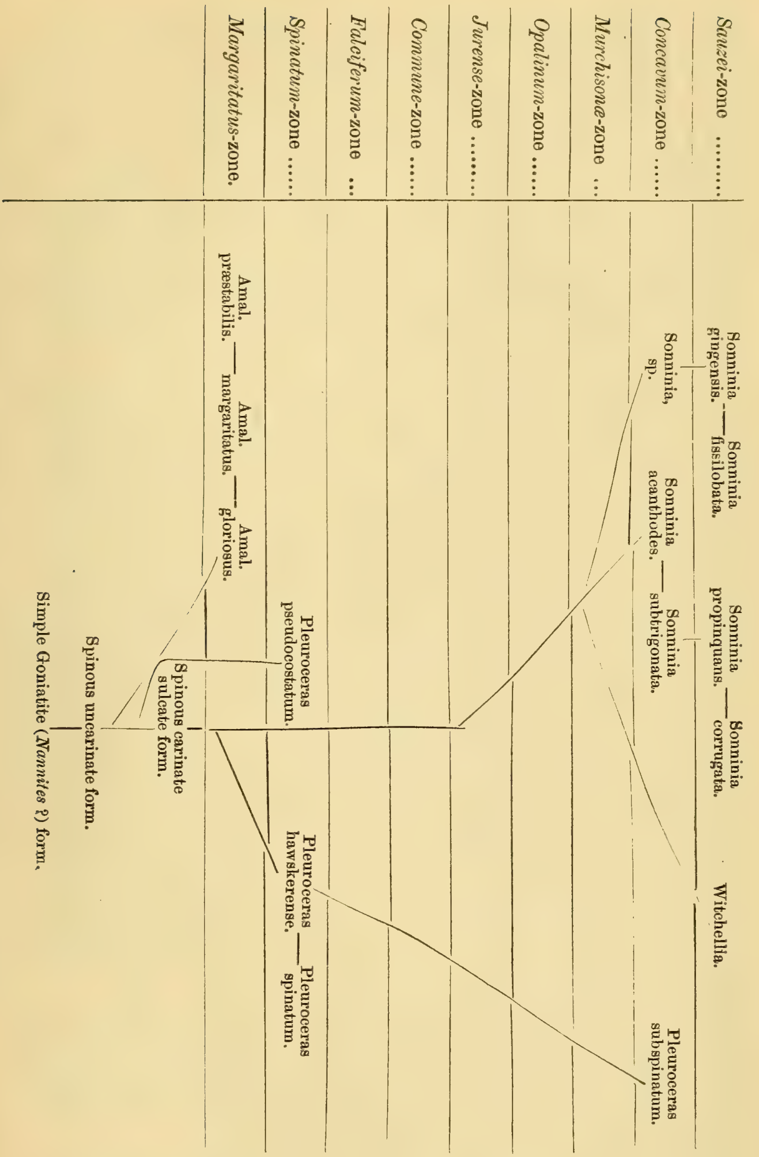
The first three of the above correspond in every way with the changes observable in the inner whorls of *Pleuroceras spinatum*, &c. Number 4 corresponds practically in most respects, but differs in the decrease of the sulci, while the spines have become more prominent.

The annexed Table (p. 655) is intended to represent the manner in which *Sonninia* is related to *Pleuroceras* and *Amaltheus*, in accordance with these developments.

The most remarkable point in the Table is the absence of all species from the *Falciferum*- to the *Murchisonæ*-zone, and yet that we should find in the *Concavum*-zone an undoubted *Pleuroceras*. In the

* In the adult *Sonninia acanthodes* these sulci are almost obsolete. Still the rudimentary sulci are very important, because they are marks of descent from a sulcate ancestor. They are persistent in the adults of all the less-developed *Sonniniæ*—those with broad ventral area; but are absent in the more highly-developed forms, *Sonn. Sowerbyi, propinquans,* &c.

The Descent of Sonninia.



face of this fact the absence of links between *Sonninia* and *Pleuroceras* cannot be used as an argument against the connexion of the latter with the former. If we now trace the further development of *Sonninia*, we shall see that it follows the same lines which had been followed by *Amaltheus*, from *Amal. gloriosus* to *Amal. præstabilis*. It is true that we shall not find the crenulated carina; but I cannot regard the absence of this as disproving the descent of *Sonninia* and *Pleuroceras* from a common ancestor. We shall, however, find that, as in *Amaltheus*, the spines are displaced by ribs, at first irregularly, and afterwards altogether; that the ribs become gradually less prominent, and finally give place to smoothness; that the whorl becomes broader, the involution greater, the ventral area thinner, until, instead of the spinous, quadrangular-whorled, evolute *Sonninia acanthodes*, we have the smooth, flat, disciform species misnamed *Sonn. corrugata* *.

Accompanying these changes we see a development of the suture-line in the matter of complexity; in fact, we see the same development as that which occurred from the sutures of young *Pleuroceras*—and possibly younger *Amaltheus*—to those of the adult *Amaltheus margaritatus*. The accompanying Plate (Pl. XXII.) will illustrate this matter.

Fig. 6 shows the suture-line of a very young *Sonninia*; it resembles a Goniatite-suture. Fig. 7 depicts the suture of *Sonninia* when somewhat older, and shows the resemblance to fig. 1, the suture of *Pleur. pseudocostatum*. Figs. 8, 9 show the great change which has taken place to develop that simple suture into such a complex one, which is, however, in its turn comparable with fig. 4 (half-grown *Amal. margaritatus*). Fig. 10 is the suture of a half-grown *Sonninia corrugata*—it is fig. 9 developed and pressed into a smaller space. In complexity it has passed far beyond fig. 4, and is comparable only with the adult *Amal. margaritatus*, fig. 5. The sole difference between the two is that the lateral lobes of fig. 10 are lower than in fig. 5; but this is caused by the extra length of the siphonal lobe in fig. 5. Now in *Amal. margaritatus* the ventral area is practically non-existent, and the two branches of the siphonal lobe have been converted into lateral lobes. As soon as that takes place we get an increase in the size of these branches because they have to support, not an arched ventral area, but a compressed, flattened side.

This resemblance of the sutures of *Amaltheus* and *Sonninia* is most extraordinary, and only to be explained if we surmise that the genera are descended from a common ancestor, and that while one branch, *Amaltheus*, accelerated its development, the other delayed that process until a much later period.

The supposition that *Sonninia* is descended from *Hammatoceras* or from *Haugia* leaves this extraordinary resemblance quite unaccounted for. Figs. 16–20 show the suture-line of *Hammatoceras*.

* Another remarkable feature furnishing a piece of strong evidence is the appearance, occasionally, of the spiral lines and also something like the wrinkle-layer of *Amaltheus* in certain species of the *Sonninia*-branch.

and the deep siphonal lobe and the obliquely directed inner lobes are constant features not found in anything like this degree in *Sonninia*. Fig. 17 shows how early these characteristics are produced and how this suture-line differs from fig. 7. These characters are found in the genera *Deroceras*, *Stephanoceras*, *Sphæroceras*, &c., showing to what *Hammatoceras* is related *.

Figs. 13–15 show the sutures of *Haugia*. The lobes are much broader-stemmed, and do not exhibit the peculiar cruciform arrangement of the trifurcations seen in the lateral lobe of *Sonninia*, while the auxiliary lobes are different.

If the inner whorls of a highly developed *Sonninia*, whose ancestry we do know, were to indicate the changes which have taken place, it would be a strong argument in favour of the correctness of the surmises which we have drawn from the inner whorls of *Sonn. acanthodes*. This is exactly what we find to be the case. The inner whorls of *Sonn. corrugata*, Sow. (*Amm. patella*, Waagen), are, in miniature, *Sonn. propinquans*, Bayle; the inner whorls of the latter are, in miniature, *Sonninia subtrigonata*, n. sp.; while the inner whorls of this are, in miniature, *Sonninia acanthodes*. The first two species occur in the *Sauzei*-zone, the two latter in the next zone below, the *Concavum*-zone.

In considering the development of the smooth *Amal. præstabilis* from the spinous *Amal. gloriosus*, and the smooth *Sonn. corrugata* from the spinous *Sonn. acanthodes*, we may, I think, assume that the gradual extinction of spines and ribs is not wholly due to advancing decrepitude. Some, if not a very large, allowance must be made for the increase in the complexity of the suture-line; and I fancy it is not too much to say that the failure of external ornaments is in a great measure due to this increase in the complexity of the suture-line—it being a matter of compensation; while the increase in the suture-complications is necessitated by the change of whorl-shape —from evolution to involution, and from arched to flattened sides.

The thin, compressed, highly-developed *Amaltheus* died out as soon almost as it appeared; the evolute *Sonninia*-ancestor with its large whorls lived to produce descendants in the *Concavum*- and *Sauzei*-zones; while *Pleuroceras*, which we may regard as somewhat intermediate between the two in point of development—though more like *Sonninia*—also produced a descendant in the *Concavum*-zone.

This was *Pleuroceras subspinatum*, Buckm.†, the descendant of *Pleur. hawskerense*. It has changed very little. Its whorls are still quadrangular and are a trifle more compressed, but, singularly enough, without more inclusion; the ribs are smaller and more numerous, the spines are therefore necessarily smaller; the sulcations of the ventral area are still prominent; but the crenulations of the carina are almost entirely obsolete—they can just be seen with a glass in some cases; the suture-line (fig. 3) agrees in the general

* Of the species now placed in the genus *Erycites* some have been referred to *Stephanoceras* and some to *Hammatoceras*. The suture-line (fig. 21) shows the characters of *Hammatoceras*, but differs in the smallness of the siphonal lobe, the functions of which have been usurped by the superior lateral lobe.

† Proc. Dorset Club, vol. iv. pl. ii. (1883).

disposition and proportion of the lobes and saddles, while differing only in minor points; the same deep superior lateral saddle is noticeable in both species (figs. 2 & 3).

Another genus, an offspring of the *Sonninia*-ancestor, may be recognized in *Witchellia.* It bears marks of its descent, especially in the deeply furrowed ventral area—furrowed, that is, when the test is absent. It also shows its descent and its relationship to *Sonninia* by the occasional production of sharp spines on the inner whorls. However, specimens which show these spines are certainly rare *. The appearance of spines must be regarded as a case of reversion, and since it is not accompanied by any other difference from the normal form, the feature cannot be considered even of specific value. Another point in which *Witchellia* indicates its descent is by the long ventral projection of the ribs—a character seen in *Amaltheus* and *Pleuroceras*, though not so conspicuous in *Sonninia.* The suture-line may be described as a *Sonninia*-suture-line with broad-stemmed lobes, or as a *Pleuroceras*-suture-line which has acquired auxiliary lobes and more ornamentation in accordance with an expanded side. (Figs. 11, 12.)

A consideration of the suture-line and the presence of small spines leads me to the conclusion that *Witchellia* parted from the *Sonninia*-parent-stem before the birth of the *Sonninia-acanthodes*-form.

The least developed species of *Witchellia* is undoubtedly the evolute *W. Sutneri* (Branco). By various intermediate—undescribed—species, each acquiring a smaller umbilicus, a broader whorl, and losing their ribs earlier in life, it is connected with or develops into *Witchellia læviuscula* (Sowerby). One of the intermediate species attains 11 inches in diameter; but *W. læviuscula* decreases to $4\frac{1}{2}$ inches, and sometimes loses its ribs at one inch. A further mutation of *W. læviuscula* loses the distinctive ventral furrows when adult.

Conclusions.

1. The genus *Sonninia* and other cognate genera are correctly separated from the Hildoceratidæ, *i. e.* the descendants of *Arietites,* and also from *Hammatoceras* and its allies, *i. e.* descendants of *Deroceras.*

2. The genus *Sonninia* and other cognate genera can be either included directly in the Family Amaltheidæ, or can be classed in a subfamily thereof.

Descriptions of New Species.

Sonninia acanhtodes, n. sp. (Pl. XXII. figs. 6, 7, 22, 23.)

Discoidal, evolute, hollow-carinate. Whorls circular, ornamented with arcuate ribs projected ventrally, and with large spines on the middle of the lateral area at irregular intervals. Ventral area not defined; carina hollow, not very prominent, on the core

* It has come to pass that the spinous stage is omitted on account of the early inheritance of later stages. Omissions of this kind have been frequently noted by Prof. Hyatt.

almost obsolete but bordered by two rudimentary sulci. Inner margin not defined. Inclusion barely one fourth, leaving a space between the spines and the succeeding whorl.

The above description applies more particularly to immature specimens. When full-grown the whorls become subquadrate, the ventral area is flatter and better defined, the inner margin is flat, and the lateral spines give place to very coarse ribs.

The size and persistence of spines which are not in contact with the succeeding whorl, and the inner margin not defined until late in life, are the characteristics of this species. The strong spines sufficiently separate it from *Sonn. polyacantha* (Waagen), which is probably its direct descendant.

It occurs in the *Concavum*-zone at Bradford Abbas, Dorset, and reaches a diameter of nine inches.

Sonninia subtrigonata, n. sp.

Discoidal, somewhat compressed, hollow-carinate. Whorls at two inches diameter almost circular, ornamented with arcuate ribs, which are directed somewhat backwards, and then have a pronounced forward sweep on the ventral area; on the middle of the lateral area are coarse, irregular spines. After a diameter of two inches, the whorls are more triangular in shape and drawn out ventrally, the ribs are more prominent, and large irregular bosses appear on the edge of the inner margin; from these bosses or from between them the ribs spring. Ventral area not defined. Carina hollow and prominent, on the core nearly obsolete, and, up to a diameter of two inches, bordered by rudimentary furrows. Inner margin not actually defined. Inclusion about two fifths—the spines being touched by the succeeding whorl.

This species is somewhat like Quenstedt's *Amm. Sowerbyi trigonatus* (Schwäbischen Jura, pl. lxi. f. 14); but it has more spines on the inner whorls, is more coarsely ornamented, has its ribs directed more backwards, has a less triangular aperture and a much larger carina. The greater thickness, coarser ribs, bosses on inner area instead of median spines, and more triangular shape separate it from *Sonn. Sowerbyi.*

The inner whorls of this species are practically a somewhat included *Sonn. acanthodes* in miniature.

The specimen is from Sherborne, probably from the *Concavum*-zone.

Part II.—*Hammatoceras.*

The descent of *Hammatoceras* involves the supposition of an actual reversion in the matter of ornament and in the size of the umbilicus. That *Hamm. insigne* is descended from *Deroceras armatum* seems to be very probable, not only on account of the similarity of suture-line, but also because of the similarity of ornament. Quenstedt allows us to form some idea of the manner in which *Dero-*

ceras armatum passed into *Hamm. insigne*. His figures of *Amm. armatus nodofissus* (Amm. Schwäbischen Jura, pl. xxvi. figs. 8–13) give us an important clue—the spines or knobs have crept very near to the inner margin, and the form is becoming involute.

If we imagine this form to have proceeded one step further in development in the ordinary way, it would have become more involute, and the spines or knobs would have disappeared. The young of *Hamm. insigne* are thick, involute, and have no knobs on the inner margin. Now comes the reversion. Instead of continuing to become more involute, the young *Hamm. insigne* grows a wider umbilicus, and at the same time reassumes the spines or knobs upon the inner margin. But the greater umbilical width is not accompanied by any increase in the thickness of the whorls, so *Hamm. insigne* increases but little in thickness after the period of the change. Both young and old differ from *Amm. nodofissus* by the possession of a small solid carina; my specimens do not allow me to say when this commenced.

We thus have three stages in the development of *Hamm. insigne*, the *armatus*-stage, the *nodofissus*-stage, and the *insignis*-stage. The next development of *Hammatoceras* may be called the *subinsignis*-stage; and it is noticeable that, in the growth of the *subinsignis*-forms, the *nodofissus*-stage—the intermediate or involute stage—is omitted altogether, so that we should find no clue to it in the inner whorls*. The *subinsignis*-stage shows a still further reversion—the knobs growing into actual spines, and coming more into the middle of the lateral area—seen to most advantage in *Hamm. dolium*, n. sp. From the small solid carina of *insignis* this stage develops the large trenchant *hollow*-carina; while it foreshadows the next or *amaltheiforme*-stage in its broader, more compressed whorls losing their ornaments, and this trenchant carina, when adult.

This last stage is seen to most perfection in *Hamm. amplectens*, n. sp., in which involution has attained its utmost limit—short of a closed umbilicus; while the whorl is discoidal, and almost without any ornaments when adult.

Another branch of *Hammatoceras* developed into *Hamm. plan-insigne*, Vacek; this into *Hamm. tenuinsigne*, Vacek; and this into *Hamm. climacomphalum* (Vacek), with the same result—the production of an involute, discoidal, almost unornamented form.

In *Hamm. amplectens* and *Hamm. climacomphalum*, which are the most changed forms of the genus, we see the same discoidal shape, with small umbilicus, which appertains to the most developed† forms of so many genera, such as *Amaltheus præstabilis*, *Sonninia corrugata*, *Lioceras*, *Hyperlioceras*. The former even bears great resemblance to *Oppelia subradiata*; while the latter has an extra-

* Traces of an intermediate stage are often omitted. Thus *Lioceras* shows no traces of the sulcate ventral area of its *Arietan*-ancestor.

† This term is used somewhat arbitrarily to express the species which have gone through the greatest number of changes to arrive at their shape, without taking into consideration whether the later changes are a decadence or otherwise.

ordinary resemblance to the species in the zone of which it occurs, namely, *Lioceras concavum.*

This is what may be called convergence (in outward shape) of the ultimate changes—in other words, senile convergence.

Conclusions.

1. *Hammatoceras* is remote from *Sonninia* by descent, in spite of outward similarity.

2. It is descended from *Deroceras* and is therefore allied to—is a cousin of—*Stephanoceras.*

3. The inclusion of *Hammatoceras, Sonninia,* and the Hildoceratidæ in one genus *Harpoceras,* merely because they possessed a carina, was most unnatural.

It may be interesting to note that the following have been identified among the species of *Hammatoceras* which occur in England:—

	Jurense-zone.	*Opalinum*-zone.	*Murchisonæ*-zone.	*Concavum*-zone.
Hamm. insigne (*Schubler*)	*			
—— subinsigne (*Oppel & Dumortier*)	...	*		
—— Alleoni (*Dum.*)	...	*		
—— Sieboldi (*Oppel*)	...	...	*	
—— dolium, n. sp	...	...	*	
—— allobrogense, mutation of	...	...	*	
—— planinsigne (*Vacek*)	...	...	*	
—— climacomphalum (*Vacek*)	...	...	...	*
—— amaltheiforme (*Vacek*)	...	...	...	*
—— amplectens, n. sp.	...	...	...	*

Descriptions of New Species.

Hammatoceras dolium, n. sp. (Pl. XXII. figs. 17, 18.)

1886. *Hammatoceras subinsigne,* Vacek (non Oppel & Dumortier), "Oolithe Cap S. Vigilio," Abh. k.-k. geol. Reichsanstalt, Bd. xii. pl. xiv. figs. 1–4.

Discoidal, somewhat compressed, hollow-carinate. Whorls elliptical to subquadrate, ornamented with spines—placed almost upon the middle of the whorl—from which coarse ribs proceed, generally in triplets, to meet the carina at right angles, and these ribs are, practically, persistent up to the carina. The part of the whorl inside the spines is smooth, possessing a series of small undulations opposite the spines. Ventral area not defined. Carina not large, distinct, hollow. Inclusion up to the spines; umbilicus open and ornamented with spines almost to the centre. As the species advances towards adolescence the spines give place to elongate, coarse, primary ribs,

which in turn gradually become less prominent; but the secondary ribs continue without alteration to a very late period.

This species is remarkable for its apparent resemblance to species of *Sonninia* such as *Sonn. adicra* and *Sonn. Sowerbyi*, especially the form figured by d'Orbigny (Pal. Franç. pl. 119). In my own collection a large specimen lay under that name for many years; while in the collection of the late Dr. Wright I noticed a specimen of this species labelled "*Harp. Sowerbii.*" From any specimens of *Sonninia* this species is distinguished by its suture-line (figs. 17, 18), and by its ribs meeting the carina at right angles in youth, and with only a slight forward sweep when adult.

There are two forms of this species in my cabinet.

1. Large coarse spines and elliptical aperture, with acute ventral area (the form figured by Vacek).

2. Spines closer, smaller and more numerous; in other respects similar to 1. In mature age the spines are coarse; but in old age they disappear, while the ventral area is flatter and the whorls are more subquadrate in shape.

To *Hammatoceras subinsigne* * this species bears very great resemblance; but it has a wider umbilicus, and has its spines more nearly upon the middle of the whorl and persistent until a much later date. Looking at these facts I am doubtful if it can be a mutation of *Hamm. subinsigne*, and it seems too thick for a mutation of *H. Lorteti* (Dum.).

The horizon of this species is the *Murchisonæ*-zone. Possibly some specimens may have come from the *Concavum*-zone; but the evidence is not conclusive.

Bradford Abbas and Half-way House, Dorset, are the localities which have supplied the specimens in my cabinet.

HAMMATOCERAS AMPLECTENS, n. sp.

Discoidal, compressed, highly involute. Whorls very broad, almost smooth, ornamented with short ribs on the outer area, and some faint undulations at intervals on the side. Ventral area barely defined, sloping and ribbed, rounded where the test is absent, but otherwise ornamented with a small carina, possibly degraded from the hollow type. Inclusion covers the whole whorl, except when the body-chamber is present, and then the customary recession of the inner margin takes place. Umbilicus small and rather deep. Aperture subtriangular †.

This species is the next descendant from *Hamm. amaltheiforme* (Vacek), of which it is an actual mutation. *Hamm. amaltheiforme* was placed by Vacek in *Harpoceras*; but it is a genuine descendant of *Hamm. insigne*, and only differs from other *Hammatocerata* by com-

* I take Dumortier's figures (Etudes pal. Bassin Rhône, iv. pl. liii.) as the type, since they are the earliest figures of the species.

† The figure of *Parkinsonia wurttemburgica* given by Bayle (Explic. Carte géol. France, pl. lxix. fig. 1 only) represents exactly the *side* view of this species. This is a remarkable instance of senile convergence. Compare also *Amm. Parkinsoni compressus*, Quenstedt (Amm. Schwäbischen Jura, pl. lxxii. figs. 12 & 15), from which our species differs, outwardly, in having a carina on the ventral area instead of a smooth space.

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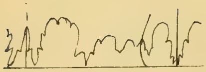

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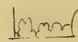

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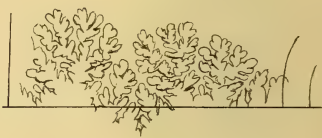

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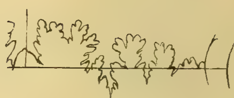

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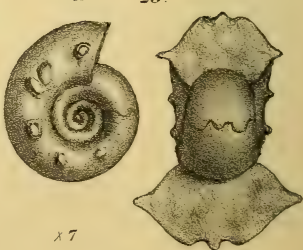

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F. H. Michael del. et lith.

SONNINIA AND

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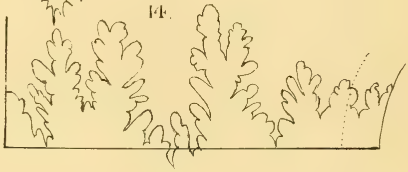

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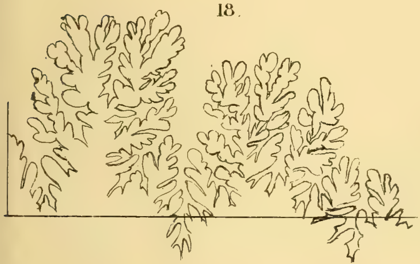

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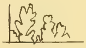

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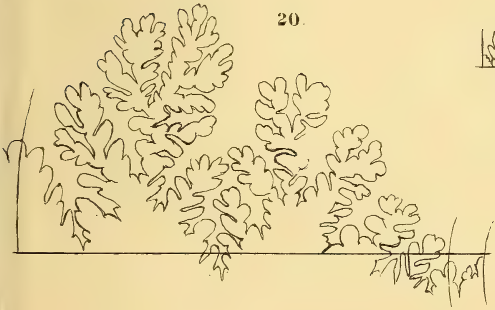

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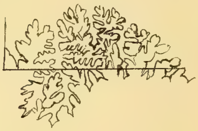

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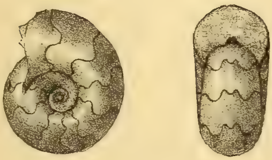

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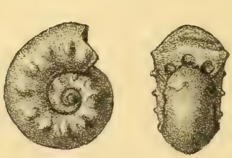

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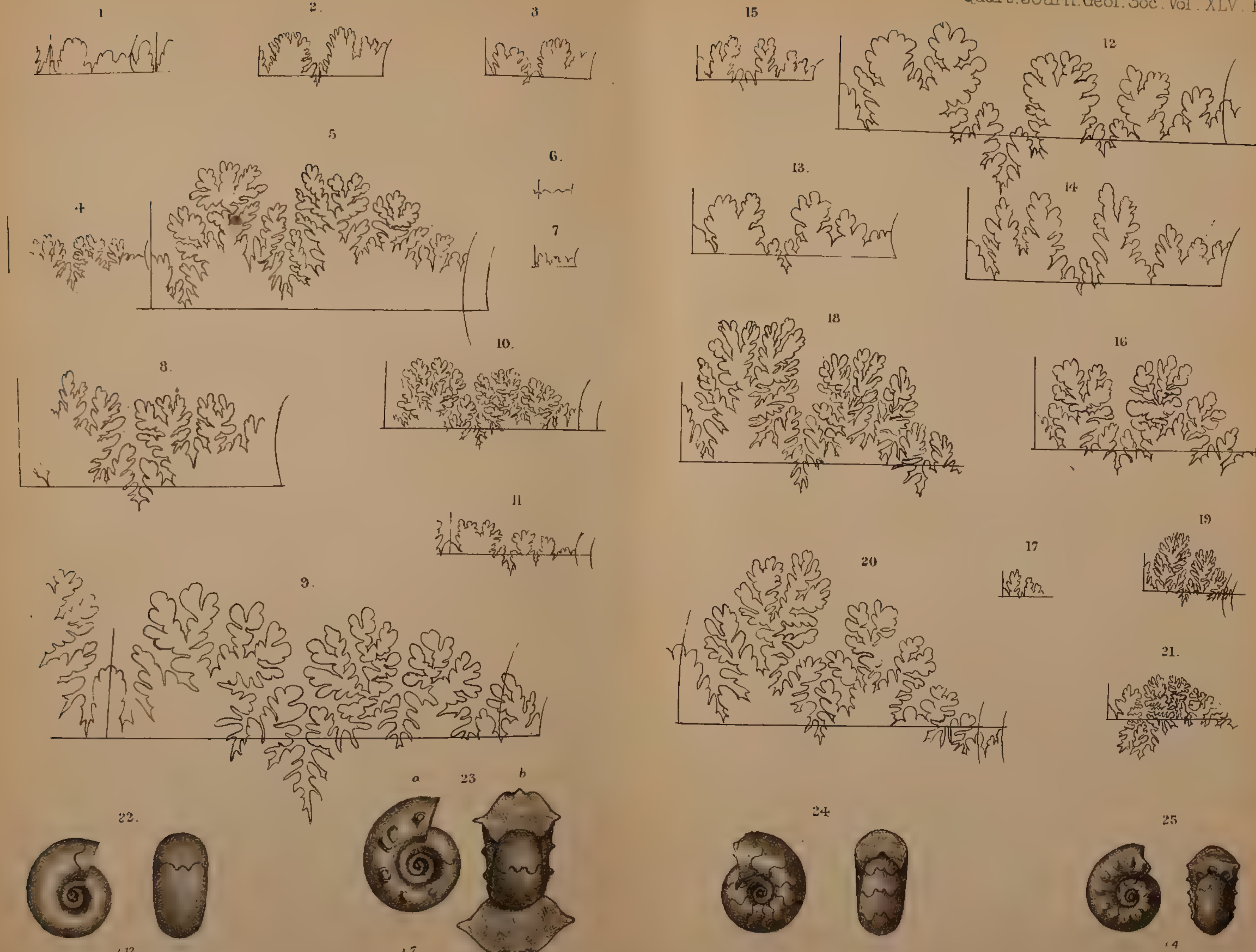
:MATOCERAS.

Mintern Bros. imp.



F. H. Michael del. et lith.

Mintern Bros. imp.

SONNINIA AND HAMMATOCERAS.

mencing the senile stage very early in life. *Hamm. amplectens* commences it still earlier; its umbilicus is much more closed, the whole form is more compressed than in *Hamm. amaltheiforme*, and, in fact, it more truly deserves that trivial name than the species to which it is applied.

Bradford Abbas and Louse Hill, Dorset, are the localities from which my specimens were obtained. The species occurs in the *Concavum*-zone and is accompanied by *Hamm. amaltheiforme*, Vacek, *Hamm. climacomphalum*, &c.

EXPLANATION OF PLATE XXII.

Fig. 1. Suture-line of a young *Pleuroceras pseudocostatum*, Hyatt, magnified 4 times.
2. ,, *Pleuroceras spinatum* (Brug.).
3. ,, *Pleuroceras subspinatum*, S. Buckm.
4. ,, *Amaltheus margaritatus*, half-grown.
5. ,, ,, adult.
6. ,, *Sonninia acanthodes*, magnified about 4 times.
7. ,, the same, when larger, to compare with fig 1. Natural size.
8. ,, *Sonninia* between *S. acanthodes* and *S. adicra* adult.
9. ,, *Sonninia*, sp., to compare with fig. 5.
10. ,, *Sonninia corrugata*, Sow., to compare with fig. 5.
11. ,, *Witchellia læviuscula*, Sow., spinous.
12. ,, *Witchellia*, sp.
13. ,, *Haugia jugosa* (Sow.).
14. ,, *Haugia Dumortieri*, S. Buckm.
15. ,, *Haugia Eseri* (Oppel).
16. ,, *Hammatoceras insigne* (Schubler).
17. ,, young *Hammatoceras dolium*, n. sp.
18. ,, adult *Hammatoceras dolium*.
19. ,, *Hammatoceras planinsigne*, Vacek.
20. ,, *Hammatoceras*, sp.
21. ,, *Erycites fallax* (Benecke), a genus allied to *Hammatoceras*. It shows how the functions of the siphonal lobe have been usurped by an inordinate expansion of the outer portion of the superior lateral lobes. This is a characteristic of *Erycites*. Note the contrary condition in fig. 5 (see page 656).
22. Inner whorls of *Sonninia acanthodes*, magnified about 12 times.
23. ,, ,, ,, ,, ,, 7 ,, *Sonninia acanthodes*, showing the commencement of the spines and the carina and sulcations.
24. ,, *Witchellia Sutneri* magnified, to compare with fig. 22.
25. ,, *Amaltheus margaritatus*, magnified about 4 times.

GENERAL INDEX

TO

THE QUARTERLY JOURNAL

AND

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

[The fossils referred to are described; and those of which the names are printed in italics are also figured.]

END OF VOL. XLV.

Printed by Taylor and Francis, Red Lion Court, Fleet Street.

PROCEEDINGS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

SESSION 1888–89.

November 7, 1888.

W. T. Blanford, LL.D., F.R.S., President, in the Chair.

Daniel Clague, Esq., 81 Lime Grove, Liverpool, was elected a Fellow, and Professor C. Renevier of Lausanne, a Foreign Member of the Society.

The List of Donations to the Library was read.

A collection of Auriferous rock-specimens from the Transvaal, South Africa, was presented to the Museum by Alfred Woodhouse, Esq., F.G.S.

The following communications were read :—

1. "The Permian Rocks of the Leicestershire Coal-field." By Horace T. Brown, Esq., F.G.S.

2. "On the Superficial Geology of the Central Plateau of North-western Canada." By J. B. Tyrrell, Esq., B.A., F.G.S., Field Geologist of the Geological and Natural History Survey of Canada*.

Specimens of rocks, microscopic sections, and photographs were exhibited by H. T. Brown, Esq., F.G.S., in illustration of his paper.

November 21, 1888.

W. T. Blanford, LL.D., F.R.S., President, in the Chair.

Thomas Charles Townsend, Esq., M.Inst. C.E., 22 Halford Road, Richmond, S.W., was elected a Fellow of the Society.

The List of Donations to the Library was read.

The names of certain Fellows of the Society were read out for

* This paper has been withdrawn by permission of the Council.

the first time, in conformity with the Bye-Laws Sect. VI B, Art. 6, in consequence of the non-payment of the arrears of their contributions.

W. Whitaker, Esq., B.A., F.R.S., F.G.S., who exhibited a series of specimens from the deep boring at Streatham, made some remarks upon the results obtained, of which the following is an abstract:—

After passing through 10 feet of gravel &c., 153 of London Clay, 88½ of Lower London Tertiaries, 623 of Chalk (the least thickness in any of the deep borings in and near London), 28½ of Upper Greensand, and 188½ of Gault, at the depth of 1081½ feet hard limestone, mostly with rather large oolitic grains, was met with. This, with alternations of a finer character, sandy and clayey, lasted for only 38½ feet, being much less than the thickness of the Jurassic beds, either at Richmond or at Meux's boring. In general character the cores showed a likeness to the Forest Marble, and the occurrence of *Ostrea acuminata* agreed therewith.

At the depth of 1120 feet the tools entered a set of beds of much the same character as those that had been found beneath Jurassic beds at Richmond, and beneath Gault at Kentish Town and at Crossness. The softer and more clayey components were not brought up; the harder consist of fine-grained compact sandstones, greenish grey, sometimes with purplish mottlings or bandings, and here and there wholly of a dull reddish tint. With these there occur hard, clayey, and somewhat sandy beds, which are not calcareous, whilst most of the sandstones are. Thin veins of calcite are sometimes to be seen, and at others small concretionary calcareous nodules; but no trace of a fossil has been found. The bedding is shown, both by the bands of colour and by the tendency of the stone to fracture, to vary generally from about 20° to 30°.

In the absence of evidence it is hard to say what these beds are, and the possibilities of their age seem to range from Trias to Devonian. It is to be hoped that this question may be solved, as on it depends that of the possibility of the presence of Coal-measures in the district; and Messrs. Docwra, the contractors of the works, have with great liberality undertaken to continue the boring-operations at their own expense for at least another week.

Details of the section will be given in a forthcoming Geological Survey Memoir, in which, moreover, the subject of the old rocks under London will be treated somewhat fully.

Discussion.

The President inquired how much had been accomplished during the last week.

Prof. Judd had not much to add to Mr. Whitaker's statement. He noticed a great similarity in character to the rocks of the Richmond boring; but at Streatham the Mesozoic beds were thinner. If an appeal was made to the scientific world, it should be done at once; it would be difficult to ask for assistance if the present character of the work was maintained.

Mr. Whitaker said that, under favourable circumstances, 30 feet a week could be accomplished. He had not much hope of a change in the character of the rocks.

The following communications were read :—

1. "Notes on the Remains and Affinities of five Genera of Mesozoic Reptiles." By R. Lydekker, Esq., B.A., F.G.S.

2. "Notes on the Radiolaria of the London Clay." By W. H. Shrubsole, Esq., F.G.S.

3. "Description of a new Species of *Clupea* (*C. vectensis*) from Oligocene Strata in the Isle of Wight." By E. T. Newton, Esq., F.G.S.

The following specimens were exhibited :—

Specimens exhibited by R. Lydekker, Esq., F.G.S., and W. H. Shrubsole, Esq., F.G.S., in illustration of their papers.

Specimens of *Clupea* exhibited by G. W. Colenutt, Esq., in illustration of the paper by E. T. Newton, Esq., F.G.S.

Specimens from the Streatham boring, exhibited by W. Whitaker, Esq., F.R.S., F.G.S.

December 5, 1888.

W. T. Blanford, LL.D., F.R.S., President, in the Chair.

John Wallwork Ashworth, Esq., Surgeon, Thorn Bank, Heaton Moor, near Stockport; James Chanter Blackmore, Esq., 11 Goldney Road, Clifton, Bristol; Gerard Weedon Butler, Esq., B.A., Blenheim Lodge, Surbiton, Surrey; Alfred Crompton, Esq., Holly Hall, Dudley; Major Frederick Hamley Fawkes, Upton Park, Slough; Harry Seymour Foster, Esq., Sutton Court, Sutton, Surrey; Charles Jesse Gilbert, Esq., Manor Hill, Sutton Coldfield; the Rev. John More Gordon, St. John's Vicarage, Redhill; John Richardson Hewitt, Esq., Albaston, near Derby; Albert Frank Stanley Kent, Esq., B.A., 33 New Street, Salisbury; the Rev. Thomas S. King, 9 Grange Road, Sheffield; C. W. Langtree, Esq., Secretary for Mines and Chief Mining Surveyor of Victoria, Mining Department, Melbourne; the Rev. James Lindsay, M.A., B.Sc., B.D., Springhill Terrace, Kilmarnock, N.B.; Reginald A. F. Murray, Esq., Government Geologist of Victoria, Mining Department, Melbourne; Max Prado, Esq., 117 Calle de los Estudios, Lima, Peru; W. H. J. Slee, Esq., Government Inspector of Mines and Superintendent of Drills, Department of Mines, Sydney, New South Wales; James John Talman, Esq., Assoc. M.Inst.C.E., 12 Delahay Street, Westminster, S.W.; and Professor A. P. W. Thomas, M.A., University College, Auckland, New Zealand, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following names of Fellows of the Society were read out for the second time in conformity with the Bye-Laws, Sect. VI. b, Art. 6, in consequence of the non-payment of the arrears of their con-

tributions:—E. K. Binns, Esq.; W. Blakemore, Esq.; A. D. Dobson, Esq.; W. Frechville, Esq.; A. Goodger, Esq.; J. Hadkinson, Esq.; H. Johnson, Esq.; G. B. Nichols, Esq.; W. G. Olpherts, Esq.; J. Richardson, Esq.; G. E. Thoms, Esq.; J. H. Tompson, Esq.; R. B. White, Esq.; and Dr. W. H. Wilson.

The following communications were read:—

1. "Notes on two Traverses of the Crystalline Rocks of the Alps." By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.

2. "On Fulgurites from Monte Viso." By Frank Rutley, Esq., F.G.S., Lecturer on Mineralogy in the Royal School of Mines.

3. "On the Occurrence of a new form of Tachylyte in association with the Gabbro of Carrock Fell, in the Lake District." By T. T. Groom, Esq. (Communicated by Prof. T. McK. Hughes, M.A., F.G.S.)

Mr. Whitaker made some remarks upon specimens obtained by the continuation of the Streatham boring from 1250 to 1258 feet. In the lowest two feet reached the rock changed in character to a hard grey micaceous sandstone containing carbonaceous fragments; a little higher up (at 1255 feet) some small objects, believed to be fish-remains, occurred in a sandstone slightly differing from that met with in the previous part of the boring. The age of these rocks was, however, said to be still uncertain.

The following specimens were exhibited:—

Rock-specimens and microscopic sections, exhibited by Prof. T. G. Bonney, D.Sc.. F.R.S., F.G.S., in illustration of his paper.

Smoothed and striated Pebbles from the Salt Range in the Punjab, probably Glacial, and of Carboniferous or Permian Age, exhibited by the President for R. D. Oldham, Esq., F.G.S.

Section of a Chalcedonified Tree-trunk from Arizona, U.S.A., exhibited by W. H. Preece, Esq., F.R.S.

Specimens and microscopic sections of Fulgurites, exhibited by Frank Rutley, Esq., F.G.S., in illustration of his paper.

Specimens and microscopic sections, exhibited by T. T. Groom, Esq., in illustration of his paper.

Specimens from the bottom of the Streatham boring, exhibited by W. Whitaker, Esq., B.A., F.R.S., F.G.S.

December 19, 1888.

W. T. Blanford, LL.D., F.R.S., President, in the Chair.

W. J. Lewis Abbott, Esq., 193 Camden Road, N.W.; John Seacome Burrows, Esq., Yew Tree House, Atherton, near Manchester; John William Evans, Esq., LL.B., B.Sc., 85 Bethune Road, N.; the Rev. Samuel Gasking, 77 Ling Street, Edgehill, Liverpool; Charles Francis Heathcote, Esq., "Clifton," Lewisham Road, Upper Norwood, S.E.; Clarence Hudson, Esq., Dowston Castle, Delph,

Oldham; Bedford MacNeill, Esq., A.R.S.M., 29 North Villas, Camden Square, N.W.; Matthew Marshall, Esq., B.A., Queen's College, Cambridge; and Francis Fielder Walton, Esq., 10 Charlotte Street, Hull, were elected Fellows of the Society.

The List of Donations to the Library was read.

The Secretary announced that two slides of Radiolaria from the London Clay of Sheppey had been presented to the Museum by W. H. Shrubsole, Esq., F.G.S., in illustration of the paper read by him on November 21, 1888.

The following communications were read:—

1. "*Trigonocrinus*, a new Genus of Crinoidea from the 'Weisser Jura' of Bavaria, with the description of a new Species, *T. liratus*; Appendix I. Sudden deviations from normal symmetry in Neocrinoidea; and Appendix II. *Marsupites testudinarius*, Schl., sp." By F. A. Bather, Esq., B.A., F.G.S.

2. "On *Archæocyathus*, Billings, and on other Genera allied thereto, or associated therewith, from the Cambrian Strata of North America, Spain, Sardinia, and Scotland." By Dr. G. J. Hinde, F.G.S.

3. "On the Jersey Brick-Clay." By Dr. Andrew Dunlop, F.G.S.

The following specimens were exhibited:—

A model of *Trigonocrinus*, exhibited by F. A. Bather, Esq., F.G.S., in illustration of his paper.

Specimens and microscopic sections of *Archæocyathus*, *Coscinocyathus*, *Spirocyathus*, *Calathium*, and other genera from the Cambrian strata of North America and Sardinia, and from the Durness Limestone of Sutherland (by permission of the Director-General of the Geological Survey), exhibited by George J. Hinde, Ph.D., F.G.S., in illustration of his paper.

Specimens of Jersey Brick-Clay, exhibited by Andrew Dunlop, M.D., F.G.S., in illustration of his paper.

Specimen and microscopic section of vitrified Brick from Guernsey, exhibited by the Rev. Edwin Hill, F.G.S.

January 9, 1889.

H. Woodward, LL.D., F.R.S., Vice-President, in the Chair.

The Rev. Edward Maule Cole, M.A., The Vicarage, Wetwang, York; Charles Gurney Thompson, Esq., St. Patrick's, Crystal Palace Park Road, Sydenham, S.E.; and Cunninghame Wilson-Moore, Esq., Assoc. Memb. Inst. C.E., Barberton, Transvaal, were elected Fellows of the Society.

The List of Donations to the Library was read.

The Secretary announced that the following works ordered by the Council to be purchased were on the table:—

Die Korallenriffe der Sinaihalbinsel—geologische und biologische Beobachtungen, von J. Walther; Die geognostichen Verhältnisse der Gegend von Krakau, von E. Tietze; Les minéraux des Roches, par A. Michel Lévy et A. Lacroix; Anleitung zu wissenschaftlichen Beobachtungen auf Reisen, von G. Neumayer (Band 1 u. 2); Introductory Text-book of Geology, by D. Page (12th edition, by C. Lapworth.)

The following communications were read:—

1. "On the Growth of Crystals in Igneous Rocks after their Consolidation." By Prof. J. W. Judd, F.R.S., F.G.S.

2. "The Tertiary Volcanoes of the Western Isles of Scotland." By Prof. J. W. Judd, F.R.S., F.G.S.

The following specimens were exhibited:—

Microscopic section and Rock-specimens, exhibited by Prof. J. W. Judd, F.R.S., F.G.S., in illustration of his paper.

Five Globes to illustrate an 'Essay on Physical Geography and Geology,' by John Thornhill Harrison, Esq., M.Inst.C.E., F.G.S., and presented by him to the Society.

January 23, 1889.

W. T. Blanford, LL.D., F.R.S., President, in the Chair.

Andrew Gibb Maitland, Esq., Geological Survey of Queensland, Brisbane, Queensland; John Millie, Esq., Echo Bank, Inverkeithing, N.B.; John Ashton Osborn, Esq., Westward Ho!, Clacton-on-Sea; James Parkinson, Esq., F.C.S., Victoria, British Columbia; and Carl Heinrich Trinks, Esq., 40 Ainger Road, Primrose Hill, N.W., were elected Fellows; the Marquis Gaston de Saporta, Aix-en-Provence, a Foreign Member; and Dr. Hans Reusch, Christiania, a Foreign Correspondent of the Society.

Visitors having withdrawn, the President announced that he, as Chairman of the Council, had, on the 10th January last, given notice to one of the Secretaries of the intention of the Council to move certain enactments, alterations, and repeals of the Bye-Laws of the Society. In accordance with Section XI. Article 8 of the Bye-Laws, the President was proceeding to read the proposed alterations *seriatim*, when it was moved by a Fellow of the Society, that as the proposed alterations were already in the hands of all Fellows present in a printed form, they should be taken as having been read. No Fellow dissenting, the President then declared that the motion of the Council had been duly read in compliance with Section XI. Article 8 of the Bye-Laws.

The following communications were read:—

1. "On the prevailing Misconceptions regarding the Evidence which we ought to expect of former Glacial Periods." By Dr. James

Croll, F.R.S. (Communicated by Prof. T. G. Bonney, D.Sc., F.R.S., F.G.S.)

2. "On Remains of Eocene and Mesozoic Chelonia, and on a Tooth of (?) *Ornithopsis*." By R. Lydekker, Esq., B.A., F.G.S.

3. "On the Dentition of *Lepidotus maximus*, Wagn., as indicated by specimens from the Kimeridge Clay of Shotover Hill, near Oxford." By R. Etheridge, Esq., F.R.S., F.G.S., and H. Willett, Esq., F.G.S.

The following specimens were exhibited:—

Specimens and casts, exhibited by R. Lydekker, Esq., F.G.S., in illustration of his paper.

Specimens of the dentition of *Lepidotus maximus*, Wagn., exhibited by R. Etheridge, Esq., F.R.S., F.G.S., and H. Willett, Esq., F.G.S., in illustration of their paper.

February 6, 1889.

W. T. Blanford, LL.D., F.R.S., President, in the Chair.

Samuel Chadwick, Esq., Mount Pleasant, Malton, Yorkshire; Percy Fry Kendall, Esq., 31 Parkfield Street, Moss Side, Manchester; and Hugh Sidney Streatfeild, Esq., The Limes, Leigham Court Road, Streatham, S.W., were elected Fellows of the Society.

The List of Donations to the Library was read.

Visitors having withdrawn, the President, in accordance with Section XI. Art. 8 of the Bye-Laws, read the motion of the Council relating to the proposed alterations in the Bye-Laws a second time. A notice of motion signed by Mr. T. V. Holmes and twelve other Fellows of the Society, and likewise one signed by Dr. George J. Hinde and nine other Fellows of the Society, were read by the President from the Chair in accordance with Sect. XI. Art. 8 of the Bye-Laws.

The following communication was read:—

"On the Occurrence of Palæolithic Flint Implements in the neighbourhood of Ightham, Kent, their Distribution and probable Age." By Joseph Prestwich, D.C.L., F.R.S., F.G.S.

A Collection of Flint Implements was exhibited by Messrs. B. Harrison and De Barri Crawshay, to illustrate the paper by Prof. J. Prestwich, D.C.L., F.R.S., V.P.G.S.

ANNUAL GENERAL MEETING,

February 15, 1889.

Dr. W. T. Blanford, F.R.S., President, in the Chair.

Report of the Council for 1888.

In presenting their Report for the year 1888, the Council have again the pleasure of being able to congratulate the Fellows upon the continuance of the prosperity of the Society. The Income of the Society was considerably larger than in 1887, so that, even after the Investment of a sum of about £160, a respectable balance remains at the credit of the Society.

The number of Fellows elected during the year is 68, of whom 49 paid their fees before the end of the year, making with 3 previously elected Fellows, who paid their fees in 1888, and 2 Fellows re-admitted without payment of Entrance-fee, a total accession during the year of 54 Fellows. During the same period, however, there was a loss by death (ascertained) of 59 Fellows, and by resignation of 15 Fellows, while 23 Fellows were removed from the List for non-payment of their annual contributions, making a total loss of 97 Fellows. There is thus an actual decrease of 43 in the total number of Fellows of the Society. This diminution is entirely accounted for by two items :—(1) the deaths include the names of 28 Fellows who died in former years, but whose decease has only recently been ascertained; (2) the number of names removed exceeds the average of the last five years by 16, owing to the Council having carried out the Bye-Laws relating to arrears more strictly. Of the 59 Fellows deceased, 8 were Compounders, 17 Contributing Fellows, and 34 Non-contributing Fellows. Owing to 7 Contributing Fellows having compounded for their subscriptions during the year, the number of Contributing Fellows is reduced by 8, being now 832.

The total number of Fellows, Foreign Members and Foreign Correspondents was 1413 at the end of the year 1887, and 1373 at the close of 1888.

At the end of the year 1887 there were 3 vacancies in the List of Foreign Members, and in the course of the year 1888 intelligence was received of the death of 2 Foreign Members. During the year 4 Foreign Members were elected. At the close of 1887 there were also 2 vacancies in the List of Foreign Correspondents, and the filling up of 4 of those among the Foreign Members produced in all

6 vacancies in the List of Foreign Correspondents, 5 of which were filled up during the year. Thus, at the close of the year 1888, there was 1 vacancy in the List of Foreign Members of the Society, and 1 in that of its Foreign Correspondents.

The total Receipts on account of Income for the year 1888 were £2866 16*s.* 10*d.*, being £339 15*s.* 6*d.* more than the estimated Income for the year. The ordinary current Expenditure of the year, leaving out of account the sum of £159 9*s.* 2*d.* expended in the purchase of £164 7*s.* 3*d.* Consolidated $2\frac{3}{4}$ per cent. Stock, was £2580 6*s.* 11*d.*, being £69 6*s.* 11*d.* in excess of the Estimate. The actual excess of Receipts over Expenditure during the year amounted to £286 9*s.* 11*d.*, and the Balance in favour of the Society to £248 12*s.* 5*d.*

In accordance with the announcement made in the Report of the Council for 1887, the Council early in the past year (on March 14, 1888) appointed a Committee to consider whether any, and what, alterations in the Bye-Laws of the Society were necessary or desirable. The Committee, which consisted of the President, with 5 Members of the Council, and 5 Fellows not at the time on the Council, met several times in the course of the summer and formulated a considerable number of suggested alterations. Their final Report was submitted to the Council at the first Meeting of the present Session on 7th November, 1888, discussed at the two succeeding Meetings, and finally, on the 5th December, 1888, referred to the Society's Solicitor, with instructions to submit it to an Equity Draughtsman, in order to obtain a legal opinion upon the alterations proposed, and as to the forms to be observed in carrying them into operation. Counsel's suggestions having been considered by the Council on the 9th January 1889, and for the most part adopted, the existing Bye-Laws and the proposed alterations were ordered to be printed and sent out to the Fellows of the Society, and on the 23rd January the requisite notice was given from the Chair at the Ordinary Evening Meeting. The Special General Meeting for the discussion of the alterations proposed will be called as soon as all the necessary formalities have been gone through.

In the month of September last the International Geological Congress held its fourth Meeting in London, when the Society's House was visited by many Foreign Geologists, several of whom passed a considerable amount of time in the examination of specimens contained in the Collections. During the Meeting the President held a reception in the rooms of the Society; this was very largely attended, and appeared to cause great satisfaction to the visitors.

The Council have to announce the completion of Vol. XLIV., and the commencement of Vol. XLV. of the Society's Quarterly Journal.

The Council have awarded the Wollaston Medal to Prof. T. G. Bonney, D.Sc., F.R.S., in recognition of the important services rendered by him to Geological Science, especially in the Department of Petrology.

The Murchison Medal, with the sum of Ten Guineas from the proceeds of the Fund, has been awarded to Prof. James Geikie, LL.D., F.R.S.L. & E., in recognition of the value of his researches in various departments of Geology, especially in connexion with Glacial Phenomena.

The Lyell Medal, with a sum of Twenty-five Pounds from the proceeds of the Fund, has been awarded to Prof. W. Boyd-Dawkins, M.A., F.R.S., in testimony of appreciation of his Palæontological investigations, especially in relation to the Fossil Mammalia.

The Bigsby Medal has been awarded to Mr. J. J. Harris Teall, M.A., F.G.S., in acknowledgment of the importance of his investigations into the structure and composition of Rocks, and of the value of his Petrographic work.

The balance of the proceeds of the Wollaston Donation Fund has been awarded to Mr. Arthur Smith Woodward, F.G.S., in token of appreciation of his excellent work in fossil Ichthyology, and to assist him in the further prosecution of his researches.

The balance of the proceeds of the Murchison Geological Fund is awarded to Mr. Grenville A. J. Cole, F.G.S., as a testimony to the value of his petrological work, and to aid him in further carrying on his investigations.

The Balance of the proceeds of the Lyell Geological Fund has been awarded to M. Louis Dollo, in recognition of the importance of his work upon the Wealden Reptilia of Belgium in connexion with the Royal Museum at Brussels, and to aid him in the further prosecution of his researches.

Report of the Library and Museum Committee.

Library.

Since the last Anniversary Meeting a great number of valuable additions have been made to the Library both by donation and by purchase.

As Donations the Library has received about 125 volumes of separately published works and Survey Reports, and 373 pamphlets and separate impressions of Memoirs, besides about 123 volumes and 149 parts of the publications of various Societies. Further, 17 volumes of independent Periodicals, presented chiefly by their respective Editors, and 18 volumes of Newspapers have been received. This constitutes a total addition to the Society's Library, by donation, of about 320 volumes and 373 pamphlets.

A great number of Maps, Plans, and Charts have been added to the Society's Collection by presentation, chiefly from the Ordnance Survey of Great Britain, whose donations amount to 1147 sheets, large and small. From the French Dépôt de la Marine 37 sheets of charts and coast-plans have been received.

Of Geological-Survey publications the Society has received a considerable number. From the Geological Survey of Great Britain 84 sheets of Maps and Sections; 2 sheets from the Geological Survey of Bavaria, 7 from that of Saxony, 1 from that of Italy, 2 from that of Finland, and 1 from that of Russia; from the Roumanian Geological Bureau 5 sheets have been received, and from more distant regions 2 from the Geological Survey of New Jersey, and 9 from the Imperial Geological Survey of Japan. The Society has further received a copy of a sheet of the Geological Map of Europe prepared by M. Hauchecorne for the International Geological Congress, and coloured in accordance with the system proposed to be adopted by that body; and, from individual donors, a geological Map of the Bath District by Mr. H. B. Woodward, and one of the Rayan depression in Egypt by Mr. Cope Whitehouse.

The Society has also received from Mr. J. T. Harrison a set of five globes prepared by him in illustration of an Essay on the production of changes of Climate in Geological time by the shifting of the position of the poles of the Earth.

The Books, Maps, &c. above referred to have been received from 168 personal Donors, the Editors or Publishers of 16 Periodicals, and 184 Societies, Surveys, and other Public Bodies, making, in all, 368 Donors.

By purchase, on the recommendation of the Standing Library Committee, the Library has received the addition of 35 volumes of books, and of 19 volumes and 15 parts (making about 5 volumes) of various Periodicals, besides 29 parts of certain works in course of publication serially. Six sheets of the Geological Map of France and the neighbouring districts, by MM. Vasseur and Carez, have also been purchased.

The cost of Books, Periodicals, and Maps purchased during the year 1888 was £68 9*s.* 4*d.*, and that of Binding £79 15*s.* 7*d.*, making a total of £148 4*s.* 11*d.*

Museum.

During the past year the following additions have been made to the Society's Museum:—

1. A considerable series of rock-specimens from Porto Rico presented by Dr. A. T. Amadeo;
2. Specimens of Rubies in their matrix, collected in Burmah by Mr. C. Barrington Brown, and presented by H.M. Secretary of State for India;
3. A collection of Auriferous rock-specimens from the Transvaal, presented by Mr. A. Woodhouse, F.G.S.; and
4. Two slides of Radiolaria from the London Clay of Sheppey, presented by Mr. W. H. Shrubsole, F.G.S.

In accordance with a statement contained in the last Report of the Committee, the cleaning of the collections in the Museum was commenced as soon as the days began to increase in length, and continued during the months of March, April, and May. The whole of the collections in the Cabinets of the Museum and Workroom were thoroughly cleaned, the drawers containing the British Collection furnished with paper covers carefully fitted so as to prevent the accumulation of dust, and there being an unemployed balance of the sum of Thirty Pounds placed by the Council in the hands of the Committee, this was devoted to fitting with glass covers a certain number of the drawers in the lower part of the Museum in which the Foreign Collections are deposited*. The Committee propose to procure additional glass covers from time to time until the whole of the drawers in the Lower Museum are so protected.

* The Expenditure in connexion with the cleaning of the Museum was as follows:—

Labour	£20	14	6
Paper, &c.	2	4	1
Glass	6	6	8
Sundry expenses	0	8	1
	£29	13	4

Leaving a balance of 6*s.* 8*d*

Comparative Statement of the Number of the Society at the close of the years 1887 and 1888.

	Dec. 31, 1887.		Dec. 31, 1888.
Compounders	312	......	311
Contributing Fellows......	840	......	832
Non-contributing Fellows ..	186	......	152
	1338		1295
Foreign Members	37	......	39
Foreign Correspondents....	38	......	39
	1413		1373

Comparative Statement explanatory of the Alterations in the Number of Fellows, Foreign Members, and Foreign Correspondents at the close of the years 1887 *and* 1888.

Number of Compounders, Contributing and Non-contributing Fellows, December 31, 1887		1338
Add Fellows elected during former year and paid in 1888		3
Add Fellows elected and paid in 1888		49
Add Fellows re-elected and who pay no Admission Fee		2
		1392
Deduct Compounders deceased	8	
Contributing Fellows deceased	17	
Non-contributing Fellows deceased	34	
Contributing Fellows resigned	15	
Contributing Fellows removed	23	
	—	97
		1295

Number of Foreign Members and Foreign Correspondents, December 31, 1887		75
Deduct Foreign Members deceased	2	
Foreign Correspondents elected Foreign Members	4	
	—	6
		69
Add Foreign Members elected		4
Foreign Correspondents elected		5
		— 78
		1373

Deceased Fellows.

Compounders (8).

Bright, Sir C. T.
Devine, T., Esq.
Eassie, W., Esq.
Feddon, F., Esq.
I'Anson, E., Esq.
Lee, H., Esq.
Richardson, J. W. H., Esq.
Robinson, A., Esq.

Resident and other Contributing Fellows (17).

Armstrong, H. B., Esq.
Bartlett, W. H., Esq.
Bell, R. G., Esq.
Collins, J., Esq.
Crichton, A., Esq.
Crowley, J. S., Esq.
Duncan, Lieut.-Col. F.
Fulcher, P. H. C., Esq.
Hichens, Major-Gen. W.
Lea, J. W., Esq.
Lewis, Prof. H. C.
Medlycott, Sir W. C. P.
Millar, Dr. J.
Pennington, R., Esq.
Pinchin, R., Esq.
Spratt, Vice-Admiral T. A. B.
Trickett, S., Esq.

Non-contributing Fellows (34).

Baily, W. H., Esq.
Brown, Prof. J.
Browne, Rev. H.
Carnegy, Dr. C. H.
Collet, T., Esq.
Cooke, Rev. R. B.
Courtney, C. F. A., Esq.
Cox, Dr. T.
Currie, Rev. C.
Drummond, Lieut.-Col. H.
Forster, W., Esq.
Griffin, T., Esq.
Hamilton, C. W., Esq.
Herbert, J. W., Esq.
Jack, Col. A.
Lloyd, Dr. G.
Maclennan, Rev. A.
Molony, Gen. C. P.
Morgans, T., Esq.
Morris, E., Esq.
Northwick, Lord.
Ogilby, W., Esq.
Ouchterlony, Lieut. J.
Parry, F. C., Esq.
Phillips, J., Esq.
Pringle, Capt. J. W.
Shaw, Dr. J.
Smyth, R. B., Esq.
Stuart, G., Esq.
Watson, J. Y., Esq.
Webster, W. B., Esq.
Wedgwood, H. A., Esq.
Wilson, Prof. J.
Witts, Rev. E. F.

Foreign Members (2).

Kjerulf, Prof. Th.
Vom Rath, Prof. G.

Fellows Resigned (15).

Baldry, J. D., Esq.
Buller, Sir W. L.
Cliff, J., Esq.
Coode, Sir J.
Deeley, J., Esq.
Dixon, S. B., Esq.
Evans, Rev. W. F.
Gillespie, Dr. F.
Grieve, D., Esq.
Lewes, Dr. P. P.
Ridley, W., Esq.
Sharman, Rev. W.
Thorpe, W. G., Esq.
Todd, Rev. J. W.
Tremenheere, Major-Gen. G. B.

Fellows Removed (23).

Binns, E. K., Esq.
Blakemore, W., Esq.
Chamberlin, Rev. T. C. B.
Cole, W. M., Esq.
Colvin, A., Esq.
Dobson, A. D., Esq.
Fremersdorff, W. F., Esq.
Gillman, F., Esq.
Goodger, A., Esq.
Hadkinson, J., Esq.
Leech, A., Esq.
Lewis, Rev. E. R.
Liversidge, H., Esq., jun.
Nichols, G. B., Esq.
Olpherts, W. G., Esq.
Parkinson, J., Esq.
Paul, G., Esq.
Richardson, J., Esq.
Tate, Dr. G.
Thoms, G. E., Esq.
Tompson, J. H., Esq.
Walker, R. B. N., Esq.
White, R. B., Esq.

The following Personages were elected from the List of Foreign Correspondents to fill the vacancies in the List of Foreign Members during the year 1888.

Professor Pierre J. van Beneden, of Louvain.
Professor Eugène Renevier, of Lausanne.
Baron Ferdinand von Richthofen, of Berlin.
Professor Gerhard Vom Rath, of Bonn.

The following Personages were elected Foreign Correspondents during the year 1888.

Professor W. C. Brögger, of Stockholm.
Mons. Charles Brongniart, of Paris.
Professor Edward Salisbury Dana, of New Haven, U.S.A.
Professor Anton Fritsch, of Prague.
Mons. Ernest Van den Broeck, of Brussels.

After the Reports had been read, it was resolved:—

That they be received and entered on the Minutes of the Meeting, and that such parts of them as the Council shall think fit be printed and distributed among the Fellows.

It was afterwards resolved:—

That the thanks of the Society be given to Dr. Henry Woodward, retiring from the office of Vice-President.

That the thanks of the Society be given to Dr. H. Hicks, J. W. Hulke, Esq., Prof. T. Rupert Jones, R. Lydekker, Esq., and Dr. H. Woodward, retiring from the Council.

After the Balloting-glasses had been duly closed, and the Lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year:—

OFFICERS.

PRESIDENT.

W. T. Blanford, LL.D., F.R.S.

VICE-PRESIDENTS.

John Evans, D.C.L., LL.D., F.R.S.
Prof. T. McKenny Hughes, M.A.
Prof. J. W. Judd, F.R.S.
Prof. J. Prestwich, M.A., D.C.L., F.R.S.

SECRETARIES.

W. H. Hudleston, Esq., M.A., F.R.S.
J. E. Marr, Esq., M.A.

FOREIGN SECRETARY.

Sir Warington W. Smyth, M.A., F.R.S.

TREASURER.

Prof. T. Wiltshire, M.A., F.L.S.

COUNCIL.

Prof. J. F. Blake, M.A.
W. T. Blanford, LL.D., F.R.S.
Prof. T. G. Bonney, D.C.L., LL.D., F.R.S.
James Carter, Esq.
John Evans, D.C.L., LL.D., F.R.S.
L. Fletcher, Esq., M.A.
A. Geikie, LL.D., F.R.S.
Prof. A. H. Green, M.A., F.R.S.
Rev. Edwin Hill, M.A.
W. H. Hudleston, Esq., M.A., F.R.S.
Prof. T. McKenny Hughes, M.A.
Prof. J. W. Judd, F.R.S.
Major-Gen. C. A. McMahon.
J. E. Marr, Esq., M.A.
E. Tulley Newton, Esq.
Prof. J. Prestwich, M.A., D.C.L., F.R.S.
F. W. Rudler, Esq.
Prof. H. G. Seeley, F.R.S.
Sir Warington W. Smyth, M.A., F.R.S.
W. Topley, Esq., F.R.S.
Rev. G. F. Whidborne, M.A.
Prof. T. Wiltshire, M.A., F.L.S.
Rev. H. H. Winwood, M.A.

LIST OF
THE FOREIGN MEMBERS
OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1888.

Date of Election.

1827. Dr. H. von Dechen, *Bonn.* (*Deceased.*)
1848. James Hall, Esq., *Albany, State of New York.*
1851. Professor James D. Dana, *New Haven, Connecticut.*
1853. Count Alexander von Keyserling, *Rayküll, Russia.*
1856. Professor Robert Bunsen, For. Mem. R.S., *Heidelberg.*
1857. Professor H. B. Geinitz, *Dresden.*
1859. Dr. Ferdinand Römer, *Breslau.*
1866. Dr. Joseph Leidy, *Philadelphia.*
1867. Professor A. Daubrée, For. Mem. R.S., *Paris.*
1871. Dr. Franz Ritter von Hauer, *Vienna.*
1874. Professor Alphonse Favre, *Geneva.*
1874. Professor E. Hébert, *Paris.*
1874. Professor Albert Gaudry, *Paris.*
1875. Professor Fridolin Sandberger, *Würzburg.*
1875. Professor Theodor Kjerulf, *Christiania.* (*Deceased.*)
1875. Professor F. August Quenstedt, *Tübingen.*
1876. Professor E. Beyrich, *Berlin.*
1877. Dr. Carl Wilhelm Gümbel, *Munich.*
1877. Dr. Eduard Suess, *Vienna.*
1879. Major-General N. von Kokscharow, *St. Petersburg.*
1879. M. Jules Marcou, *Cambridge, U. S.*
1879. Dr. J. J. S. Steenstrup, For. Mem. R.S., *Copenhagen.*
1880. Professor Gustave Dewalque, *Liége.*
1880. Baron Adolf Erik Nordenskiöld, *Stockholm.*
1880. Professor Ferdinand Zirkel, *Leipzig.*
1882. Professor Sven Lovén, *Stockholm.*
1882. Professor Ludwig Rütimeyer, *Basle.*
1883. Professor J. S. Newberry, *New York.*
1883. Professor Otto Martin Torell, *Stockholm.*
1884. Professor G. Capellini, *Bologna.*
1884. Professor A. L. O. Des Cloizeaux, For. Mem. R.S., *Paris.*
1884. Professor G. Meneghini, *Pisa.* (*Deceased.*)
1884. Professor J. Szabó, *Pesth.*
1885. Professor Jules Gosselet, *Lille.*
1886. Professor Gustav Tschermak, *Vienna.*
1887. Professor J. P. Lesley, *Philadelphia.*
1887. Professor J. D. Whitney, *Cambridge, U.S.*
1888. Professor Pierre J. van Beneden, *Louvain.*
1888. Professor Eugène Renevier, *Lausanne.*
1888. Professor Gerhard Vom Rath, *Bonn.* (*Deceased.*)
1888. Baron Ferdinand von Richthofen, *Berlin.*

LIST OF

THE FOREIGN CORRESPONDENTS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1888.

Date of Election.	
1863.	Dr. F. Senft, *Eisenach.*
1864.	Dr. Charles Martins, *Montpellier.*
1866.	Professor Victor Raulin, *Bordeaux.*
1866.	Baron Achille de Zigno, *Padua.*
1872.	Herr Dionys Stur, *Vienna.*
1874.	Professor Igino Cocchi, *Florence.*
1874.	M. Gustave H. Cotteau, *Auxerre.*
1874.	Professor G. Seguenza, *Messina.* (*Deceased.*)
1874.	Dr. T. C. Winkler, *Haarlem.*
1877.	Professor George J. Brush, *New Haven.*
1877.	Count Gaston de Saporta, *Aix-en-Provence.*
1879.	M. Edouard Dupont, *Brussels.*
1879.	Dr. Émile Sauvage, *Paris.*
1880.	Professor Luigi Bellardi, *Turin.*
1880.	Professor Leo Lesquereux, *Columbus.*
1880.	Dr. Melchior Neumayr, *Vienna.*
1880.	M. Alphonse Renard, *Brussels.*
1881.	Professor E. D. Cope, *Philadelphia.*
1882.	Professor Louis Lartet, *Toulouse.*
1882.	Professor Alphonse Milne-Edwards, *Paris.*
1883.	Professor Karl Alfred von Zittel, *Munich.*
1884.	Dr. Charles Barrois, *Lille.*
1884.	M. Alphonse Briart, *Morlanwelz.*
1884.	Professor Hermann Credner, *Leipzig.*
1884.	Baron C. von Ettingshausen, *Gratz.*
1884.	Dr. E. Mojsisovics von Mojsvár, *Vienna.*
1885.	M. F. Fouqué, *Paris.*
1885.	Professor G. Lindström, *Stockholm.*
1885.	Dr. A. G. Nathorst, *Stockholm.*
1886.	Professor H. Rosenbusch, *Heidelberg.*
1886.	Professor J. Vilanova y Piera, *Madrid.*
1887.	Senhor J. F. N. Delgado, *Lisbon.*
1887.	Professor A. Heim, *Zurich.*
1887.	Professor A. de Lapparent, *Paris.*
1888.	Professor W. C. Brögger, *Stockholm.*
1888.	M. Charles Brongniart, *Paris.*
1888.	Professor Edward Salisbury Dana, *New Haven, U.S.A.*
1888.	Professor Anton Fritsch, *Prague.*
1888.	M. Ernest Van den Broeck, *Brussels.*

AWARDS OF THE WOLLASTON MEDAL

UNDER THE CONDITIONS OF THE "DONATION FUND"

ESTABLISHED BY

WILLIAM HYDE WOLLASTON, M.D., F.R.S., F.G.S., &c.

To promote researches concerning the mineral structure of the earth, and to enable the Council of the Geological Society to reward those individuals of any country by whom such researches may hereafter be made,"—"such individual not being a Member of the Council."

1831. Mr. William Smith.
1835. Dr. G. A. Mantell.
1836. M. Louis Agassiz.
1837. { Capt. T. P. Cautley. Dr. H. Falconer.
1838. Sir Richard Owen.
1839. Professor C. G. Ehrenberg.
1840. Professor A. H. Dumont.
1841. M. Adolphe T. Brongniart.
1842. Baron L. von Buch.
1843. { M. Elie de Beaumont. M. P. A. Dufrénoy.
1844. Rev. W. D. Conybeare.
1845. Professor John Phillips.
1846. Mr. William Lonsdale.
1847. Dr. Ami Boué.
1848. Rev. Dr. W. Buckland.
1849. Professor Joseph Prestwich.
1850. Mr. William Hopkins.
1851. Rev. Prof. A. Sedgwick.
1852. Dr. W. H. Fitton.
1853. { M. le Vicomte A. d'Archiac. M. E. de Verneuil.
1854. Sir Richard Griffith.
1855. Sir H. T. De la Beche.
1856. Sir W. E. Logan.
1857. M. Joachim Barrande.
1858. { Herr Hermann von Meyer. Mr. James Hall.
1859. Mr. Charles Darwin.
1860. Mr. Searles V. Wood.
1861. Professor Dr. H. G. Bronn.
1862. Mr. R. A. C. Godwin-Austen.
1863. Professor Gustav Bischof.
1864. Sir R. I. Murchison.
1865. Dr. Thomas Davidson.
1866. Sir Charles Lyell.
1867. Mr. G. Poulett Scrope.
1868. Professor Carl F. Naumann.
1869. Dr. H. C. Sorby.
1870. Professor G. P. Deshayes.
1871. Sir A. C. Ramsay.
1872. Professor J. D. Dana.
1873. Sir P. de M. Grey-Egerton.
1874. Professor Oswald Heer.
1875. Professor L. G. de Koninck.
1876. Professor T. H. Huxley.
1877. Mr. Robert Mallet.
1878. Dr. Thomas Wright.
1879. Professor Bernhard Studer.
1880. Professor Auguste Daubrée.
1881. Professor P. Martin Duncan.
1882. Dr. Franz Ritter von Hauer.
1883. Dr. W. T. Blanford.
1884. Professor Albert Gaudry.
1885. Mr. George Busk.
1886. Professor A. L. O. Des Cloizeaux.
1887. Mr. J. Whitaker Hulke.
1888. Mr. H. B. Medlicott.
1889. Professor T. G. Bonney.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE WOLLASTON "DONATION-FUND."

1831. Mr. William Smith.
1833. Mr. William Lonsdale.
1834. M. Louis Agassiz.
1835. Dr. G. A. Mantell.
1836. Professor G. P. Deshayes.
1838. Sir Richard Owen.
1839. Professor C. G. Ehrenberg.
1840. Mr. J. De Carle Sowerby.
1841. Professor Edward Forbes.
1842. Professor John Morris.
1843. Professor John Morris.
1844. Mr. William Lonsdale.
1845. Mr. Geddes Bain.
1846. Mr. William Lonsdale.
1847. M. Alcide d'Orbigny.
1848. { Cape-of-Good-Hope Fossils. M. Alcide d'Orbigny. }
1849. Mr. William Lonsdale.
1850. Professor John Morris.
1851. M. Joachim Barrande.
1852. Professor John Morris.
1853. Professor L. G. de Koninck.
1854. Dr. S. P. Woodward.
1855. Drs. G. and F. Sandberger.
1856. Professor G. P. Deshayes.
1857. Dr. S. P. Woodward.
1858. Mr. James Hall.
1859. Mr. Charles Peach.
1860. { Professor T. Rupert Jones. Mr. W. K. Parker. }
1861. Professor A. Daubrée.
1862. Professor Oswald Heer.
1863. Professor Ferdinand Senft.
1864. Professor G. P. Deshayes.
1865. Mr. J. W. Salter.
1866. Dr. Henry Woodward.
1867. Mr. W. H. Baily.
1868. M. J. Bosquet.
1869. Mr. W. Carruthers.
1870. M. Marie Rouault.
1871. Mr. R. Etheridge.
1872. Dr. James Croll.
1873. Professor J. W. Judd.
1874. Dr. Henri Nyst.
1875. Mr. L. C. Miall.
1876. Professor Giuseppe Seguenza.
1877. Mr. R. Etheridge, Jun.
1878. Professor W. J. Sollas.
1879. Mr. S. Allport.
1880. Mr. Thomas Davies.
1881. Dr. R. H. Traquair.
1882. Dr. G. J. Hinde.
1883. Mr. John Milne.
1884. Mr. E. Tulley Newton.
1885. Dr. Charles Callaway.
1886. Mr. J. S. Gardner.
1887. Mr. B. N. Peach.
1888. Mr. J. Horne.
1889. Mr. A. Smith Woodward.

AWARDS OF THE MURCHISON MEDAL

AND OF THE

PROCEEDS OF "THE MURCHISON GEOLOGICAL FUND,"

ESTABLISHED UNDER THE WILL OF THE LATE

SIR RODERICK IMPEY MURCHISON, Bart., F.R.S., F.G.S.

"To be applied in every consecutive year in such manner as the Council of the Society may deem most useful in advancing geological science, whether by granting sums of money to travellers in pursuit of knowledge, to authors of memoirs, or to persons actually employed in any inquiries bearing upon the science of geology, or in rewarding any such travellers, authors, or other persons, and the Medal to be given to some person to whom such Council shall grant any sum of money or recompense in respect of geological science."

1873. Mr. William Davies. *Medal.*
1873. Professor Oswald Heer.
1874. Dr. J. J. Bigsby. *Medal.*
1874. Mr. Alfred Bell.
1874. Professor Ralph Tate.
1875. Mr. W. J. Henwood. *Medal.*
1875. Professor H. G. Seeley.
1876. Mr. A. R. C. Selwyn. *Medal.*
1876. Dr. James Croll.
1877. Rev. W. B. Clarke. *Medal.*
1877. Professor J. F. Blake.
1878. Dr. H. B. Geinitz. *Medal.*
1878. Professor C. Lapworth.
1879. Professor F. M'Coy. *Medal.*
1879. Mr. J. W. Kirkby.
1880. Mr. R. Etheridge. *Medal.*
1881. Professor A. Geikie. *Medal.*
1881. Mr. F. Rutley.
1882. Professor J. Gosselet. *Medal,*
1882. Professor T. Rupert Jones.
1883. Professor H. R. Göppert. *Medal.*
1883. Mr. John Young.
1884. Dr. H. Woodward. *Medal.*
1884. Mr. Martin Simpson.
1885. Dr. Ferdinand Römer. *Medal.*
1885. Mr. Horace B. Woodward.
1886. Mr. W. Whitaker. *Medal.*
1886. Mr. Clement Reid.
1887. Rev. P. B. Brodie. *Medal.*
1887. Mr. Robert Kidston.
1888. Professor J. S. Newberry. *Medal.*
1888. Mr. E. Wilson.
1889. Professor James Geikie. *Medal.*
1889. Mr. Grenville A. J. Cole.

AWARDS OF THE LYELL MEDAL

AND OF THE

PROCEEDS OF THE "LYELL GEOLOGICAL FUND,"

ESTABLISHED UNDER THE WILL AND CODICIL OF THE LATE
SIR CHARLES LYELL, Bart., F.R.S., F.G.S.

The Medal "to be given annually" (or from time to time) "as a mark of honorary distinction as an expression on the part of the governing body of the Society that the Medallist has deserved well of the Science,"—"not less than one third of the annual interest [of the fund] to accompany the Medal, the remaining interest to be given in one or more portions at the discretion of the Council for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced."

1876. Professor John Morris. *Medal.*
1877. Dr. James Hector. *Medal.*
1877. Mr. W. Pengelly.
1878. Mr. G. Busk. *Medal.*
1878. Dr. W. Waagen.
1879. Professor Edmond Hébert. *Medal.*
1879. Professor H. A. Nicholson.
1879. Dr. Henry Woodward.
1880. Mr. John Evans. *Medal.*
1880. Professor F. Quenstedt.
1881. Sir J. W. Dawson. *Medal.*
1881. Dr. Anton Fritsch.
1881. Mr. G. R. Vine.
1882. Dr. J. Lycett. *Medal.*
1882. Rev. Norman Glass.
1882. Professor C. Lapworth.
1883. Dr. W. B. Carpenter. *Medal.*
1883. Mr. P. H. Carpenter.
1883. M. E. Rigaux.
1884. Dr. Joseph Leidy. *Medal.*
1884. Professor Charles Lapworth.
1885. Professor H. G. Seeley. *Medal.*
1885. Mr. A. J. Jukes-Browne.
1886. Mr. W. Pengelly. *Medal.*
1886. Mr. D. Mackintosh.
1887. Mr. Samuel Allport. *Medal.*
1887. Rev. Osmond Fisher.
1888. Professor H. A. Nicholson. *Medal.*
1888. Mr. A. H. Foord.
1888. Mr. T. Roberts.
1889. Professor W. Boyd Dawkins. *Medal.*
1889. M. Louis Dollo.

AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY

DR. J. J. BIGSBY, F.R.S., F.G.S.

To be awarded biennially "as an acknowledgment of eminent services in any department of Geology, irrespective of the receiver's country; but he must not be older than 45 years at his last birthday, thus probably not too old for further work, and not too young to have done much."

1877. Professor O. C. Marsh.
1879. Professor E. D. Cope.
1881. Dr. C. Barrois.
1883. Dr. Henry Hicks.
1885. Professor Alphonse Renard.
1887. Professor Charles Lapworth.
1889. Mr. J. J. Harris Teall.

AWARDS OF THE PROCEEDS OF THE BARLOW-JAMESON FUND,

ESTABLISHED UNDER THE WILL OF THE LATE

DR. H. C. BARLOW, F.G.S.

"The perpetual interest to be applied every two or three years, as may be approved by the Council, to or for the advancement of Geological Science."

1880. Purchase of microscope.
1881. Purchase of microscope lamps.
1882. Baron C. von Ettingshausen.
1884. Dr. James Croll.
1884. Professor Leo Lesquereux.
1886. Dr. H. J. Johnston-Lavis.
1888. Museum.

ESTIMATES *for*

INCOME EXPECTED.

	£ s. d.	£ s. d.
Compositions		199 10 0
Due for Arrears of Admission-fees	75 12 0	
Admission-fees, 1889	226 16 0	
		302 8 0
Due for Arrears of Annual Contributions		105 0 0
Annual Contributions, 1889, from Resident Fellows, and Non-residents, 1859 to 1861		1533 0 0
Annual Contributions in advance		42 0 0
Dividends on Consolidated $2\frac{3}{4}$ per Cents.		243 16 8
Sale of Quarterly Journal, including Longman's account	170 0 0	
Sale of Geological Map, including Stanford's account	7 0 0	
Sale of Transactions, Library-catalogue, Ormerod's Index, Hochstetter's New Zealand, and List of Fellows	3 0 0	
		180 0 0
		£2605 14 8

THOMAS WILTSHIRE, TREAS.

2 *Feb.* 1889.

the Year 1889.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes	25	0	0			
Fire-insurance	15	0	0			
Gas	30	0	0			
Fuel	32	0	0			
Furniture and Repairs	15	0	0			
House-repairs and Maintenance	15	0	0			
Annual Cleaning	20	0	0			
Washing and Sundries	33	0	0			
Tea at Meetings	16	0	0			
				201	0	0
Salaries and Wages:						
Assistant Secretary	350	0	0			
Assistants in Library, Office, and Museum	240	0	0			
House Steward	105	0	0			
Housemaid	40	0	0			
Errand Boy	48	0	0			
Charwoman and Occasional Assistance	25	0	0			
Attendants at Meetings	8	0	0			
Accountant	10	10	0			
				826	10	0
Official Expenditure:						
Stationery	25	0	0			
Miscellaneous Printing	60	0	0			
Postages and other Expenses	100	0	0			
				185	0	0
Library				150	0	0
Museum				5	0	0
Publications:						
Geological Map	10	0	0			
Quarterly Journal	950	0	0			
" " Commission, Postage, and Addressing	100	0	0			
List of Fellows	33	0	0			
Abstracts, including Postage	110	0	0			
				1203	0	0
Balance in favour of the Society				35	4	8
				£2605	14	8

Income and Expenditure during the

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in Bankers' hands, 1 January 1888.	115	18	11			
Balance in Clerk's hands, 1 January 1888.	5	12	9			
				121	11	8
Compositions				199	10	0
Arrears of Admission-fees	18	18	0			
Admission-fees, 1888	308	14	0			
				327	12	0
Arrears of Annual Contributions				207	14	0
Annual Contributions for 1888, viz.:						
Resident Fellows	1517	5	0			
Non-Resident Fellows	15	15	0			
				1533	0	0
Annual Contributions in advance				54	12	0
Dividends and Bonus on Consols and Reduced 3 per Cents., now converted into 2¾ per Cents.				321	8	7
Taylor & Francis: Advertisements in Journal, Vol. 43				3	14	9
Publications:						
Sale of Journal, Vols. 1–43	123	13	3			
,, Vol. 44 *	79	18	0			
Sale of Library Catalogue	2	1	0			
Sale of Geological Map	8	17	9			
Sale of Ormerod's Index	2	2	6			
Sale of Hochstetter's New Zealand	0	6	0			
Transactions	1	8	0			
Abstracts	0	2	8			
				218	9	2
Journal Subscriptions in Advance				0	16	4
				£2988	8	6

	£	s.	d.
*Due from Messrs. Longmans, in addition to the above, on Journal, Vol. 44, &c.	60	3	6
Due from Mr. Stanford on account of Geological Map	6	18	8
	67	2	2

We have compared this statement with the Books and Accounts presented to us, and find them to agree.

(Signed) L. FLETCHER, F. W. RUDLER, } *Auditors.*

2 *February*, 1889.

Year ending 31 *December*, 1888.

EXPENDITURE.

	£	s.	d.	£	s.	d.	£	s.	d.
House Expenditure:									
Taxes				24	14	2			
Fire-insurance				15	0	0			
Gas				28	13	8			
Fuel				30	12	0			
Furniture and Repairs				20	3	4			
House-repairs, Ordinary				12	2	5			
Annual Cleaning				13	4	9			
Washing and Sundries				36	4	2			
Tea at Meetings				16	0	0			
							196	14	6
Salaries and Wages:									
Assistant Secretary				350	0	0			
Assistants in Library, Office, and Museum				220	0	0			
House Steward				105	0	0			
Housemaid				40	0	0			
Errand Boy				47	9	0			
Charwoman				23	1	6			
Attendants at Meetings				8	0	0			
Accountant's Fee				10	10	0			
							804	0	6
Official Expenditure:									
Stationery				29	17	2			
Miscellaneous Printing				21	3	0			
Postages and other Expenses				89	1	3			
							140	1	5
Library							148	4	11
Museum							1	0	6
Publications:									
Geological Map				4	6	6			
Journal, Vols. 1–43				69	12	6			
„ Vol. 44	969	0	6						
„ „ Commission, Postage, and Addressing	101	17	6						
				1070	18	0			
List of Fellows				33	12	6			
Abstracts, including Postage				110	9	10			
Ormerod's Index				1	3	9			
Transactions				0	2	0			
							1290	5	1
Investment of £164 7*s*. 3*d*. Consolidated $2\frac{3}{4}$ per Cents. at $96\frac{7}{8}$							159	9	2
Balance in Bankers' hands, 31 Dec. 1888				232	6	0			
Balance in Clerk's hands, 31 Dec. 1888				16	6	5			
							248	12	5
							£2988	8	6

"Wollaston Donation Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January, 1888	31	10	2	Cost of striking Gold Medal awarded to Mr. H. B. Medlicott	10	10	0
Dividends and Bonus on the Fund invested in Reduced 3 per Cents., now converted into $2\frac{3}{4}$ per Cents.	34	7	2	Award to Mr. J. Horne	21	0	2
				Balance at Bankers', 31 December, 1888	34	7	2
	£65	17	4		£65	17	4

"Murchison Geological Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January, 1888	19	7	6	Award to Prof. J. S. Newberry, with Medal	10	10	0
Dividends on the Fund invested in London and North-Western Railway 4 per cent. Debenture Stock	38	17	6	" Mr. E. Wilson	27	8	10
				Cost of Medal	0	17	0
				Balance at Bankers', 31 December, 1888	19	9	2
	£58	5	0		£58	5	0

"Lyell Geological Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January, 1888	51	3	1	Award to Dr. H. A. Nicholson, with Medal	25	0	0
Dividends on the Fund invested in Metropolitan $3\frac{1}{2}$ per cent. Stock	68	9	0	" Mr. A. H. Foord	21	1	10
				" Mr. T. Roberts	21	1	9
				Cost of Medal	1	1	0
				Balance at Bankers', 31 December, 1888	51	7	6
	£119	12	1		£119	12	1

"Barlow-Jameson Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January, 1888	34	7	2	Museum	30	0	0
Dividends and Bonus on the Fund invested in Consols, now converted into $2\frac{3}{4}$ per Cents.	19	9	7	Balance at Bankers', 31 December, 1888	23	16	9
	£53	16	9		£53	16	9

"Bigsby Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January, 1888	6	1	8	Balance at Bankers', 31 December, 1888	12	3	10
Dividends on the Fund invested in New 3 per Cents., now converted into $2\frac{3}{4}$ per Cents.	6	2	2				
	£12	3	10		£12	3	10

Valuation of the Society's Property; 31 December, 1888.

Property.	£	s.	d.		£	s.	d.		£	s.	d.
Due from Longman & Co., on account of Journal, vol. xliv. &c.				60	3	6		Balance in favour of the Society	9022	6	7
Due from Stanford on account of Map				6	18	8					
Balance in Bankers' hands, 31 Dec. 1888				232	6	0					
Balance in Clerk's hands, 31 Dec. 1888				16	6	5					
Funded Property:—	£	s.	d.								
Consolidated $2\frac{3}{4}$ per Cents. at 98	8700	0	0	8526	0	0					
Arrears of Admission-fees (considered good)				75	12	0					
Arrears of Annual Contributions (considered good)				105	0	0					
				£9022	6	7			£9022	6	7

[*N.B.—The above does not include the value of the Collections, Library, Furniture, and stock of unsold Publications.*]

THOMAS WILTSHIRE, *Treas.*

2 *Feb.* 1889.

Award of the Wollaston Medal.

In presenting the Wollaston Gold Medal to Prof. T. G. Bonney, D.Sc., F.R.S., the President addressed him as follows:—

Professor Bonney,—

A Medal that was instituted to promote researches concerning the mineral structure of the earth cannot be more appropriately awarded than for petrological studies. That the method of research has changed since Wollaston's time is largely due to the improvement of modern instruments; the work carried on by yourself and others with the microscope is in direct continuation of that done by Wollaston, his contemporaries, and many of his followers, with the goniometer, the test-tube, and the balance. In your hands the microscope has been a valuable adjunct to field-observation, and has been chiefly applied to detect the secrets of those rocks which, possessing no organic remains to betray the tale of their origin, have hitherto succeeded in baffling the curiosity of geologists as to their early history. In many parts of the British Isles, throughout the Alps, and in Canada, especially where ancient and obscure formations presented puzzles yet unsolved, you have been occupied in adding to our knowledge. Nor has your attention been confined to Archæan and Plutonic rocks; you were a leader of the opposition to the prevalent, but perhaps somewhat exaggerated view of the powers of glacial erosion, and you have applied the same key that had admitted you to the inner mysteries of metamorphic formations to unlock the history of British sedimentary rocks.

In conferring upon you the chief mark of distinction in its gift, the Council desires to evince its appreciation of your scientific researches, and the Fellows of the Society will, I feel sure, heartily endorse the presentation of the Wollaston Medal to you, who have served so long and so successfully as one of their principal officers.

Prof. Bonney, in reply, said:—

Mr. President,—

It is difficult for me adequately to express my gratitude to the Council for the great honour which they have conferred upon me, and to you for the terms in which you have spoken of my work. Of this, the defects to myself seem more conspicuous than the merits. I can only plead in excuse for those, that my work has been carried on under many difficulties on which I will not now enlarge. It has

been incomplete and preparatory, often destructive rather than constructive, that of a seeker after truths to which another generation will attain. If, indeed, there be any good in it, this is because throughout I have studied nature more than books, I have sought for reasons rather than for authorities, and in so doing have endeavoured to apply the principles of induction which I learnt years ago at Cambridge in the study of mathematics. Still, I am conscious that for this crowning honour I am indebted more to the kindly feeling of others than to my own merits, and can only promise that, if time for scientific work yet remain, I will try to become more worthy of the distinction which has been awarded to me.

Award of the Wollaston Donation Fund.

The President next presented to Mr. A. Smith Woodward, F.G.S., the Balance of the Proceeds of the Wollaston Fund, and said :—

Mr. Smith Woodward,—

In presenting to you the Balance of the Wollaston Fund, the Council of the Geological Society recognize the value of your contributions to the knowledge of fossil fishes and fossil reptiles. Your publications on these classes of animals are carefully written, and show an extensive acquaintance with the rather intricate literature of the subject. I hope that the award now handed to you will be an incentive to further researches and an assistance in prosecuting them.

Mr. Smith Woodward, in reply, said :—

Mr. President,—

I beg to express my best thanks to the Council of the Geological Society for the honour they have done me in making this award, and also to yourself, Sir, for the kind manner in which you have spoken of my slight attempts to extend the boundaries of one small department of our Science. It has always been my greatest pleasure to devote my leisure hours to the study of Natural History; and it is very gratifying to feel that the circumstances of the last few years have enabled me to follow these pursuits in a manner that is deemed worthy of recognition by this Society. Continual access to a collection like that of the British Museum affords exceptional facilities for palæontological research; and the experience gained when

assisting my late senior colleague, Mr. William Davies, in the arrangement of the unique series of Fossil Fishes, has pointed out to me a wide field for investigation among the lower extinct Vertebrates. The highly-valued encouragement received to-day will incite me to renewed efforts, and I shall still strive to make the best use of the advantages resulting from my official position.

Award of the Murchison Medal.

In handing the Murchison Medal to Mr. William Topley, F.R.S., for transmission to Professor James Geikie, LL.D., F.R.S., F.G.S., the President addressed him as follows:—

Mr. Topley,—

The Council has awarded the Murchison Medal to Professor James Geikie in acknowledgment of his important contributions to the Geology of North Britain, and especially of his investigation of glacial phenomena. His 'Great Ice-Age' contained a full, careful, and admirably written summary of the observations made up to 1874, and the interest excited by the work was proved by a second edition being required in 1877. Professor Geikie has besides published numerous papers, not the least important of which were two that appeared in the Society's Quarterly Journal containing his observations "On the Glacial Phenomena of the Long Island or Outer Hebrides."

Mr. Topley, in reply, said:—

Mr. President,—

On behalf of Prof. James Geikie, who is detained in Scotland, I beg most heartily to thank the Council of the Geological Society of London, for the honour conferred upon him in the Award of the Murchison Medal. A prize founded by and continued in honour of his old chief, will, I am sure, have for Prof. James Geikie an especial value. He has desired me to communicate to you the following remarks:—"I feel sure that my fellow geologists will fully agree with me when I say that the prosecution of our favourite science is its own great reward. The charms that first took our fancy do not lose any of their attractions after we have become confirmed devotees. On the contrary, as years pass, our interest only deepens, and we are so absorbed that happily we escape

much of the fret and fever of these bustling times. But a geologist, after all, is human, and he would be less so if he did not warmly appreciate the sympathy of his fellow hammerers. I need hardly say, therefore, that I am extremely gratified to find that I have gained the sympathy of so representative a body of geologists as the Council of this Society. The distinction which they have been so good as to confer upon me I shall cherish not only as a mark of their appreciation of the little I have done, but as an additional incentive to continued work."

Award of the Murchison Geological Fund.

In presenting the Balance of the Murchison Geological Fund to Mr. Grenville A. J. Cole, F.G.S., the President said:—

Mr. Grenville Cole,—

In the course of the last few years you have published several interesting papers on petrological subjects, and especially on spherulitic and perlitic structure, and on volcanic glasses. The Council of the Geological Society has presented you with the Balance of the Murchison Fund in recognition of your contributions to Petrology, and as a means of aiding you in extending your investigations.

Mr. Cole, in reply, said:—

Mr. President,—

This award, granted by the Council of the Geological Society, is all the more pleasant to me because so completely unexpected. It is to me but another evidence of the generous encouragement that is extended by the master-craftsmen to the apprentices in geological work.

To deal with rocks from a purely mineralogical standpoint would be to ignore the broad principles of geology marked out by the founders of the science, and it will always be my earnest endeavour, stimulated by the fellowship of this Society, to connect the minuter researches of the laboratory with the study of earth-structure in the field.

Award of the Lyell Medal.

The President then presented the Lyell Medal to Prof. W. Boyd Dawkins, F.R.S., F.G.S., and addressed him as follows :—

Professor Boyd Dawkins,—

In awarding to you the Lyell Medal for the present year, the Council of the Geological Society wishes to mark its recognition of the importance of your palæontological researches, and especially of the additions made by you to our knowledge of the Mammalia found in the later Tertiary and particularly in the Pleistocene deposits of this country. Your researches have extended over a considerable number of years, and amongst the earliest of the papers published by you were those on British fossil oxen and on the dentition of certain extinct species of Rhinoceros, all of which appeared in the Society's Quarterly Journal. Your attention has especially been directed to primæval man, his implements, and the mammals that were his contemporaries, and in your works on 'Cave Hunting' and 'Early Man in Britain' you have done much to disseminate a knowledge of scientific discoveries amongst readers whom more technical works would have repelled.

Prof. Boyd Dawkins, in reply, said :—

Mr. President,—

I thank you, from my heart, for the kind words which you have spoken in awarding to me the honour of the Lyell Medal. I feel, Sir, on looking back on the work of the last 25 years how little I have been able to do compared with what I proposed to do, and I console myself with the knowledge that this is the common experience of all workers in all subjects. My main work has been in that field of Geological inquiry which looks towards history, in which Sir Charless Lyell, the founder of the Medal, rejoiced to labour, and its results have for the most part been published in the Journal of this Society. I feel therefore peculiar gratification in receiving in the name of this Society this medal for work done in Sir Charles Lyell's favourite field. If I may speak of the future, I would say that I shall work all the harder through this mark of approbation of the Society, and that I hope to be able to do a little, in the time that is left to me, to fill up the blank which lies between our science and history.

Award of the Lyell Geological Fund.

The President next presented to M. Louis Dollo the Balance of the Proceeds of the Lyell Geological Fund, and addressed him as fellows:—

M. Dollo,—

The Reptilian Faunas of the Upper Secondary and the Tertiary strata of Belgium have only of late years become generally known to geologists. That the scientific world is now better informed concerning the wonderful remains of Cretaceous Dinosaurs, Mosasaurs, and Crocodiles, and both Cretaceous and Tertiary Chelonia from the Belgian beds is in great part due to your descriptions. In awarding to you the Balance of the Lyell Fund the Council of the Geological Society hope to aid you in prosecuting further researches.

M. Dollo, in reply, said:—

Mr. President,—

I beg to express my acknowledgments for the honour which has been bestowed upon me by the Geological Society. This encouragement will stimulate my energies in the field of palæontology, and my greatest and sincere desire is that I may, on any occasion, render myself useful to the Geological Society of London, and fully deserving of the favour which it has been pleased to confer upon me.

The nature of the researches to which I have devoted these last years has afforded me the advantage of frequent intercourse with many of the palæontologists in this country; and I wish on this occasion to express to them my indebtedness for the many encouragements I have received.

Award of the Bigsby Medal.

In presenting the Bigsby Medal to Mr. J. J. Harris Teall, F.G.S., the President said:—

Mr. Teall,—

Your contributions to the Petrology of the British Islands have had a great influence on the views of British geologists. In your papers on the dykes of Northern England and Scotland you have added much to our previous knowledge, and in your description of

the metamorphosis of dolerite into hornblende-schist you succeeded in proving what had certainly been suspected, but probably never so clearly demonstrated before, the production of foliated rocks by the action of mechanical forces on igneous formations. Your 'British Petrography,' the concluding part of which has recently appeared, contains many original observations, and well maintains the scientific character of your previous writings, whilst it supplies a much-needed desideratum to the geologists of this country. The Council of this Society, whilst awarding to you the Bigsby Medal in token of the esteem in which they hold your work, hope that your 'British Petrography' may be the precursor of other equally valuable additions to our science.

Mr. Teall, in reply, said:—

I beg to offer my sincere thanks to the Council for the honour they have conferred upon me, and to you, Sir, for the kind way in which you have referred to my work.

There is an accidental circumstance which adds to the pleasure I feel on this occasion; it is that I receive the Bigsby Medal on the day that my earliest instructor receives the highest award which this Society can give. I should not be standing here to-day if it had not been my good fortune to come in contact with Prof. Bonney at Cambridge.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

W. T. Blanford, LL.D., F.R.S.

Gentlemen,

It is our custom on these occasions, as you are aware, after doing honour to those whom the Society regards as worthy of its awards, to recall to memory those who, in the course of the year just terminated, have passed away from amongst us.

Although the tale of our losses is heavy, the number of deaths recorded in our list (61 Fellows and Foreign Members, to which I have to add one Foreign Correspondent, the news of whose death has arrived very recently), as has already been explained in the Council's Report, gives a somewhat exaggerated idea of it, many of the deaths having really taken place in previous years, although they were not reported for want of the information now procured through a thorough inquiry by our officers.

Gerhard Vom Rath, Professor of Geology and Mineralogy in the University of Bonn, died on the 23rd April last. He was born on the 20th August, 1830, at Dinsburg in Prussia. His father, who was a successful manufacturer of beetroot sugar, moved with his family to Cologne in 1840, and Vom Rath's early studies were carried on at the Jesuiten-Gymnasium of that city. In 1848 he attended the Rhenish High School at Bonn, and shortly afterwards entered the University of the same city, where he remained till 1852, when he proceeded to Berlin, and continued his studies under Rose, Weiss, Rammelsberg, and other distinguished chemists and mineralogists. At Berlin he took his Doctor's degree in July 1853, taking for his thesis a chemical and mineralogical dissertation on the composition and alteration-products of Wernerite.

After a journey to Italy, which lasted nine months, and another in company with Gustav Rose to Silesia, he returned to Bonn in 1856, and after assisting Nöggerath, then Professor of Geology and Director of the Mineralogical Museum, for some years, he was appointed Extraordinary Professor in July 1863, and Ordinary Professor of Geology and Mineralogy in April 1872. The Directorship of the Mineralogical Museum was placed in his hands in December of the same year, on the retirement of Prof. Nöggerath. In 1873, on the death of Gustav Rose, Vom Rath was offered the vacant

Professorship of Mineralogy in Berlin, but declined to leave Bonn, where he remained throughout the remainder of his life, except during the numerous journeys which he undertook after 1880. In that year he gave up his Professorships, being appointed instead "Ordinary Honorary Professor;" and during the remainder of his life he visited many parts of Europe, Palestine, and the United States. He was starting for a journey in Southern Europe when he was struck down at the Coblence railway station by a paralytic stroke which was followed shortly by his death. He was elected a Corresponding Member of this Society in 1879, and a Foreign Member last year.

The most important of Gerhard Vom Rath's numerous papers relate to mineralogy, and more especially to chemical mineralogy, though he also published many crystallographical notes. His papers have been greatly praised for exactitude. He also wrote on the geology of the countries he visited, on their physical geography, and their inhabitants. Although his name is attached to no great work, he filled an important part. To agreeable manners and wide knowledge he added an extensive acquaintance with scientific men throughout the civilized world. One proof of his influence was his success in pursuading the Prussian Government to purchase for the Mineralogical Museum at Bonn the private mineral collection, containing 14,000 specimens, of Krantz, the well-known mineral-dealer, at a price of 144,000 marks (£7200). He was an honorary or corresponding Member of numerous Academies and Societies in various parts of Europe and in the United States.

Theodor Kjerulf, Professor of Geology in the University of Christiania, and Director of the Geological Survey of Norway, was born at Christiania on March 30th, 1825, and died in the same city on October 25th, 1888. After taking his degree in the University of his native city, he went to Germany, and for some time studied in Bunsen's laboratory. In 1858 he became Professor of Geology in the Christiania University, and soon after he was placed in charge of the Norwegian Geological Survey. He became a Foreign Correspondent of this Society in 1864, and a Foreign Member in 1875.

Professor Kjerulf's contributions to the geological knowledge of his native land are extensive, and contain descriptions of most of the principal Norwegian formations, especially of those found in Southern Norway. The most important of his Survey publications, "Udsigt over det Sydlige Norges Geologi," a work of over 260 pages, with an atlas of 39 plates and a geological map, which appeared in

1879, contains the principal results of 20 years' observations in Southern Norway. Amongst the subjects to which, in this and other works, his attention was especially devoted, were the Archæan and Palæozoic rocks of Norway, and the traces of glacial action so conspicuous in parts of that country.

Sir Charles Tilston Bright, at the time of his death in May last, at the age of 56, had been a Fellow of this Society for a quarter of a century. He was born at Wanstead in 1832, educated at Merchant Taylors' School, and, at the age of 15, entered the service of the Electric Telegraph Company, established to work the patents of Cooke and Wheatstone. From this time his life was devoted to electric telegraphy, and both as inventor and as engineer his name became a "household word" in connexion with the series of enterprises that have so marvellously accelerated the means of communication between all civilized nations in the course of the last 40 years. He took a leading part in 1853 in laying a submarine cable between Portpatrick in Scotland and Donaghadee in Ireland; and in 1858, after an unsuccessful attempt in the previous year, he achieved the historical feat, as engineer, of laying the first Atlantic Cable. It is true that this cable, although successfully laid, failed shortly afterwards, but the great first step had been taken, and the task, once achieved, was soon repeated. This signal scientific victory was largely due to the previous experiments of Mr. Bright, and there has probably seldom, in modern times, been an instance in which knighthood has been more worthily bestowed than it was in this case on a young man of only 26.

For the ten or twelve years following the laying of the first Atlantic Cable, Sir C. Bright was engaged in establishing submarine communication in various parts of the world. One of the most important expeditions to which he was attached was that in 1860, of H.M.S. 'Bulldog,' and the private steam-yacht 'Fox' sent to survey a proposed route for a Transatlantic cable, *viâ* Iceland, Greenland, and Newfoundland. Later he was chiefly engaged in various commercial undertakings, most of them connected with telegraphy. He was President of the Society of Telegraph Engineers and Electricians in the Jubilee year of the Telegraph (1887), which coincided with the Jubilee year of Her Majesty's reign. So far as I can ascertain, he never wrote on any geological subject.

William Hellier Baily, who died at Rathmines, near Dublin, on August 6th, had ceased for upwards of 30 years to be a resident

of this city, but for the previous 13 years he was well known to many London geologists and to all connected in any way with the Geological Survey or the Royal School of Mines. Born at Bristol, July 7th, 1819, Mr. Baily became an assistant Curator in the Bristol Museum in 1837, and in 1844 was attached to the Geological Survey of Great Britain as draughtsman, joining the staff as Assistant Geologist under Sir H. de la Beche in the following year. From that time till 1857 he was occupied in palæontological work connected with the Survey; but in the latter year he removed to Dublin on being appointed Palæontologist to the Irish Survey, a post which he held until his death. In 1868 he received the additional appointment of Demonstrator in Palæontology to the Royal College of Science for Ireland.

Mr. Baily belonged to a group of scientific men who have now become rare in the British Islands, although they still flourish in goodly numbers in several continental countries. They were Palæontologists, but not specialists, and many of them were at the same time excellent stratigraphical geologists. Mr. Baily's first two published papers, which appeared in the eleventh and fourteenth volumes of the Society's Quarterly Journal, "Descriptions of some Cretaceous Fossils from South Africa" and "Descriptions of Fossil Invertebrata from the Crimea," belonged to a class that has grown rare in English publications at the present day. They contained identifications and descriptions of a large number of fossil species, sponges, corals, Bryozoa, Echinoderms, and Mollusca, from various beds of Jurassic, Cretaceous, and Tertiary age. The new species were described and well figured by the author himself. But two of Mr. Baily's later papers were published in the Society's Journal, the majority having appeared, either in connexion with the Irish Survey, in official publications, or in the Journals and Proceedings of the learned Societies of Dublin. In 1867 he commenced the publication of "Figures of characteristic British Fossils," and was awarded the proceeds of the Wollaston Donation Fund in aid of the work. Unfortunately the undertaking was not a pecuniary success, and only the Palæozoic portion was ever published.

One of Mr. Baily's best claims to the gratitude of his fellow-geologists consists in his admirable and artistic figures. He was an excellent draughtsman and lithographer, and in his case the talent was hereditary, both his father and grandfather having been remarkable for artistic skill, whilst his uncle, E. H. Baily, R.A., was the well-known sculptor. Personally, the object of these notes was a kind-

hearted earnest worker, and I well remember, when I was studying at the School of Mines, how ready he was to afford any of us assistance.

One of the greatest losses that the Society has sustained in 1888 is caused by the death, at the early age of 34, of Henry Carvill Lewis. He was born in Philadelphia, U.S.A., on November 16th, 1853, and graduated at the University of Pennsylvania in 1873. He remained in the University, studying Natural History, for three years after taking his M.A. degree in 1876, and from 1879 till 1884 served as a volunteer on the staff of the Geological Survey of Pennsylvania under Professor Lesley. In 1880 he was elected Professor of Mineralogy in the Academy of Natural Sciences, Philadelphia, and in 1883 he was appointed, in addition, Professor of Geology in Haverford College, Pennsylvania. He held both appointments until his death.

The question to which Professor Carvill Lewis's attention was especially devoted, whilst engaged on the staff of the Pennsylvanian Geological Survey, was the delimitation, within the State of Pennsylvania, of the old ice-sheet that covered so large a portion of North America in the Glacial period, and the mapping of the terminal moraine. To this work some other members of the Geological Survey contributed, and important assistance was given by another volunteer, the Rev. G. F. Wright. But the principal field-observations were made by Professor Carvill Lewis himself, and the "Report on the Terminal Moraine in Pennsylvania and New York," published in 1884, is entirely written by him. It is the most important work of which he was the author, and contains a mass of information not only concerning the limits of the North-American ice-sheet, but also regarding its action and effects within those limits.

In 1885 Professor Carvill Lewis came to Europe, and from that year till his untimely death was engaged during the summers in applying to England, Ireland, and portions of Germany and Switzerland the observations made on the evidence of ice-action in Pennsylvania, and during the winters in studying petrology with Prof. Rosenbusch at Heidelberg. Some of the results of Prof. Lewis's observations on the glacial phenomena of Great Britain and Ireland were presented to the British Association in 1886 and 1887; but as there were still several points on which he wished for further information, no complete account of his views was published. He,

however, distributed maps on which the limits of the various ice-sheets, as traced out by him, were laid down. Up to the Manchester Meeting of the British Association in 1887 he was disposed to attribute all Pleistocene glacial phenomena, in the British Isles as in America, to one uninterrupted period of cold; but a short notice contributed by his widow, Mrs. Lewis, to the 'Geological Magazine' shows that he had seen reason to modify his views in this respect after a visit to Frankley Hill, in Worcestershire, in company with Dr. H. W. Crosskey. Unhappily his study of the glacial phenomena of the British Isles was never completed, and the hopes entertained by many geologists of this country that much light would be thrown upon one of the most interesting, but also one of the most difficult problems in geology, by the work of one so singularly qualified for the study, were not fulfilled. In the course of a visit to America last spring, Professor Carvill Lewis was attacked by typhoid fever, from which he died at Manchester, soon after his return to Europe, on the 21st July, 1888.

The papers published by Professor Carvill Lewis on subjects not relating to the traces of the Glacial epoch were chiefly mineralogical.

To many English geologists, as to myself, Professor Carvill Lewis became first known personally at the Montreal Meeting of the British Association by the great energy and kindness with which, as the representative of the Philadelphia Committee, he gave assistance to all members of the British Association who wished to go from Montreal to the American Association Meeting at Philadelphia. No one could have been better selected as a representative of American hospitality. The charm of a peculiarly pleasant manner, a thoroughly scientific mind, and very considerable energy, have won for him in the course of the few years that have elapsed since his arrival in Europe, not only in England, but also on the continent, a large circle of friends, and the loss of one so highly esteemed, and for whom so brilliant a career was anticipated, has produced as widely spread a feeling of sorrow on this side of the Atlantic as in America.

Vice-Admiral Thomas A. B. Spratt, C.B., F.R.S., who died on the 10th March, 1888, was born in the year 1811, and entered the Navy in 1827. He was the eldest son of Commander James Spratt, who greatly distinguished himself whilst serving on board H.M.S. 'Defiance' at the battle of Trafalgar. From the commencement

of his naval career the late Admiral was attached to the surveying branch of the Navy, and served almost continuously from 1827 till 1863 in the Mediterranean, at first under Captain Thomas Graves, in H.M.SS. 'Mastiff' and 'Beacon,' and subsequently, from 1847, in command successively of H.M.SS. 'Voyage,' 'Spitfire,' and 'Medina.'

During the Crimean war, the 'Spitfire,' under Commander Spratt, was attached to the fleet then engaged in hostilities with Russia. He took part in the siege of Sebastopol, planned the attacks on Kertch and Kinburn, and led the allied fleets to their positions at the latter place. He made numerous surveys required for the anchorage or operations of the fleet, and repeatedly received the acknowledgments of Admiral Sir E. Lyons, Commanding-in-Chief, for his services. For these he was promoted to the rank of Captain in January 1855, and received the Companionship of the Bath and the rank of Officer in the Legion of Honour at the close of the war.

After the war Captain Spratt, in command of the 'Medina,' was again engaged in hydrographical surveys, chiefly in the Greek Archipelago, till 1863, when he returned to England, and did not again serve actively afloat. He was Commissioner of Fisheries from 1866 to 1873, and Acting-Conservator of the Mersey from 1879 till his death at his residence, Clare Lodge, Tunbridge Wells. He became a Fellow of this Society in 1843, and was a Member of the Council in 1866 and 1867, and again from 1876 till 1879.

Although the most important scientific work of our late Fellow was that immediately connected with the surveying branch of the Navy—and he was well known for the excellence of his surveys—he was a man of wide sympathy and cultured taste, and he not only made use of the opportunities presented to him, as to many other naval officers, for studying the geology of the regions in which he was engaged, but he devoted much time to tracing the ancient history of the Levant, and to the identification of the cities, rivers, mountains, and seaports of the classical Greek writers. At an early period of his career he had the advantage of being associated for two years with the late Professor Edward Forbes, who was engaged as Naturalist in the 'Beacon,' under Captain Thomas Graves, from 1841 to 1843, and who then made the observations on the bathymetrical distribution of marine life that led to his well-known arrangement of the fauna in submarine zones. There can be little doubt that both Lieut. Spratt and Prof. Edward Forbes profited by

this association: the former, in his 'Travels in Crete,' published many years after, repeatedly referred to Prof. Forbes as his guide in scientific inquiry; and Sir R. Murchison, in his address to the Royal Geographical Society in 1865, whilst speaking in the highest terms of the work just quoted as a "masterly illustration of the physical geography, geology, archæology, natural history, and scenery of the diversified island of Crete," adds that "without the deep soundings and dredgings conducted by Captain Spratt, we should never have obtained the grand views of Edward Forbes on the submarine zones inhabited by different classes of animals." The two friends published a joint work 'Travels in Lycia, Milyas, and the Cibyratis' in 1847, full of sketches and plans (for both were accomplished draughtsmen), and replete with details of ancient cities and of the rocks from which their building-stones were derived.

From 1845 to 1860 Captain Spratt was a not unfrequent contributor to the Society's Journal, all his papers describing the geology of various countries in the Levant. He paid especial attention to the freshwater Tertiary beds of the Greek islands, the shores of Asia Minor, and the lower valley of the Danube, and several of his communications refer to these formations. At a later period he published in our Journal some notes on the bone-caves of Malta, and on the coal-deposits of Erekli in Bithynia. But he contributed to other publications many valuable observations on deep soundings, on current-action, and on the deltas of the Nile and Danube. His principal work, however, after his retirement from active naval service was that already mentioned—his 'Travels and Researches in Crete,' in two volumes, which appeared in 1865. This gave an account of his journeys through the island in connexion with the hydrographical survey of its coasts, his identifications of ancient sites, and many notes on physical geography, geology, and zoology.

The Rt. Hon. Charles Shaw Lefevre, Viscount Eversley, G.C.B., D.C.L., Hon. M.Inst.C.E., who died December 28, 1888, had been a Fellow of this Society for 58 years. He was born in 1794, and was the eldest son of Mr. Charles Shaw, M.P. for Reading, and of Helena, the daughter of Mr. J. Lefevre, a descendant of an old French Huguenot family. Mr. Charles Shaw Lefevre was educated at Winchester and at Trinity College, Cambridge, and entered Parliament as Member for Downton in the same year in which he joined the Geological Society. He afterwards represented North Hampshire. He was Speaker from 1839 to 1857, when he became a peer and retired from public life.

Giuseppe Meneghini, Senator of the Kingdom of Italy, Professor of Geology and Mineralogy at the University of Pisa, the oldest and one of the most widely known of Italian Geologists, died on the 29th January, 1889. He was born in Padua on the 30th July, 1811, studied at the University of the same city, and took the degree of doctor of medicine there in 1834. Towards the end of the same year he became assistant to the Professor of Botany at Padua. In 1839 he received the Professorship of Physics, Chemistry, and Botany in the Medical School of the Padua University. In 1848, in consequence of political complications, he was driven from Padua; but in 1849 he was installed in Pisa as Professor of Geology and Mineralogy, and remained there till his death. The Jubilee of his professional career was celebrated in 1884.

The news of Professor Meneghini's death was telegraphed to me by his colleague, Prof. d'Achiardi, in time for me to request our Foreign Member, Prof. Capellini, who was at Pisa, to represent the Society at the funeral. This he was so good as to do.

Professor Meneghini's earlier scientific publications were chiefly botanical. Up to the time of his leaving Padua he had only written a few unimportant papers on geological subjects. Amongst his numerous subsequent contributions to various branches of science the most valuable were palæontological, especially his 'Palæontology of Sardinia,' published in 1857. To this work additions were subsequently made as new materials were obtained, and one of these, which appeared in 1881, contained descriptions of Cambrian Trilobites from the island. Another important work of Meneghini's was his 'Monograph of the Fossils belonging to the Red Limestone with Ammonites of Lombardy, the Apennines, and Central Italy.' Besides his palæontological work, he wrote a few mineralogical papers, one of the best known being that in which, in association with E. Bechi, he described some curious zeolites containing magnesia in considerable quantities.

Professor Meneghini was elected a Foreign Correspondent of this Society in 1863, and a Foreign Member in 1884.

Within the last week I have received information of the death, on the 3rd of February 1889, of another Italian Geologist, a Foreign Correspondent of this Society, Giuseppe Seguenza, Professor of Geology in the University of Messina. Owing to the death having occurred so recently, I have been unable to learn full details of his life. He was born in 1833. His writings, which were very

numerous, were chiefly devoted to the palæontology of the Tertiary beds of Sicily, and, to assist him in this work, the Wollaston Fund was awarded to him by our Council in 1876. He was elected a Foreign Correspondent in 1874.

John Brown, M.Inst.C.E., was born at Stafford in 1823, and became a Fellow of this Society in 1857. He was engineer to several different collieries in succession, that of which he was in charge the longest being the Cannock Chase Colliery, from which he retired in 1873. He became well known at this and at other collieries by the improvements which he introduced into the method of working, especially in winding-gear. Mr. Brown was at one time a partner in a firm of engineers, Brown and Jeffcock of Sheffield and Barnsley, but during a large part of his life he occupied the position of consulting engineer, his advice being widely sought by colliery owners in the midland counties. He was at different times President of both the South Staffordshire and the North Staffordshire Mining Institutes, and he was the first honorary Professor of Mining at the Mason Science College, Birmingham. His death took place in November last.

Amongst the Fellows whose names have only been removed from our list within the past twelvemonth, their deaths having been previously overlooked, there is one whose loss should not be passed over without notice. William Ogilby, M.A., F.Z.S., F.L.S., F.R.A.S., died on the 1st September, 1873, in the 65th year of his age. He was born in the north of Ireland, and was the son of Leslie Ogilby, of Liscleen, county Tyrone. He was a student of Trinity College, Cambridge, and graduated in 1829. He was called to the Bar on November 20th, 1832; and practised as a barrister in London until 1846, when he returned to Ireland, and resided for the remainder of his life at Altnachree Castle, Tyrone. He was a Magistrate and Deputy-Lieutenant of the county, and served the office of High Sheriff in 1853.

Mr. Ogilby was Hon. Secretary of the Zoological Society from 1839 to 1846, and contributed numerous papers, chiefly on Mammalia, to that Society's 'Proceedings.' He also wrote the treatise on the "Mammalogy of the Himalayas" in the Appendix to Royle's 'Himalayan Botany.' He became a Fellow of this Society in 1832; but his only contribution to its publications was a paper "On the Structure and Relations of the presumed Marsupial remains from the Stonesfield Slate," which appeared in the 'Proceedings' for 1838.

The volume of the Society's Quarterly Journal for the year 1888 is considerably thicker than that published in each of the preceding years since 1882. Increase in the bulk of a book, as all scientific workers know, and none better than geologists, is no evidence of increase in the value of its contents; many works of portentous dimensions are remarkable for nothing but their size; but in the present case the additional space has been occupied by several papers of greater length than usual, and these papers are, I think, of importance not disproportionate to their length. In fact one of the longest, the Report on recent work in the Western Highlands, by officers of the Geological Survey, is a condensed abstract of observations by several geologists extending over many years, which might easily fill, and probably, when published with full details, will fill one or more volumes. No papers aid more in maintaining the high character of our Journal than those which give the general results of an extensive series of observations, with only such details as are essential in order to enable those results to be understood.

The paper that I have just mentioned, on the recent work of the Geological Survey in the North-west Highlands, is, probably, the most important paper on Geological Dynamics that has been brought before the Society this year, perhaps for several years, even when the value of the new stratigraphical information and of the contribution to the history of metamorphism is disregarded. It is perfectly true that the principal conclusions as to the distortion of strata were not new; they had been published already by other observers, and resulted from the application of observations made by various geologists in the Alps and elsewhere; but as the geological examination of the Highlands had never before been extended over so large an area in any detail, the views adopted had not been tested by a systematic and exhaustive survey. Until this had been done, geologists were perfectly justified in suspending their judgment; but since the careful and thorough survey of Messrs. Peach and Horne and their colleagues has confirmed the views of Professor Lapworth (and in great part those of Nicol and several other observers), the theory of enormous lateral movement in rocks, involving changes in position of many miles, and the actual thrust of masses forming mountains over each other, has received a sufficient amount of confirmation to justify our believing that the problem of the actual process of mountain-formation is solved, and that it now only remains to determine the cause.

This, however, is only one of the principal questions on which

light is thrown by this Report; to many geologists the evidence showing the connexion between great terrestrial movements and the metamorphism of rocks will prove of even higher interest than the mere physical phenomena of distortion. But it is very doubtful whether there will be a similar amount of acquiescence in the results. In a subsequent paragraph I may have to call attention briefly to this question again in connexion with the apparently almost hopeless conflict of opinion on the subject of metamorphism that has been brought prominently forward by the recent Geological Congress.

Three other papers of considerable length, that by one of our Secretaries, Mr. Marr, and Prof. H. A. Nicholson, on the Stockdale Shales, that by Mr. W. Hill on the Lower Beds of the Upper Cretaceous series in Lincolnshire and Yorkshire, and that by Messrs. Gardner, Keeping, and Monckton, on the Upper Eocene, are valuable contributions to an accurate knowledge of English stratigraphy. All are the results of long and painstaking research, and in all the details are an essential part of the paper.

The fifth, the longest paper of all, that by Prof. J. F. Blake, "On the Monian System of Rocks," is perhaps the most ambitious as well. Nearly sixty years have now elapsed since Sedgwick proposed the name of Cambrian for the system that was regarded then, as by many geologists it still is, as the lowest containing organic remains. Hitherto the beds beneath the Cambrian have been classed as Pre-Cambrian or Archæan, and although many names have been conferred on local subdivisions, and some attempts, hitherto not distinguished by much success, have been made to correlate these subdivisions in different regions, the question of classification has been, almost by general consent, postponed for further information. Professor Blake, however, holds that a great system composed three subdivisions can be traced in the Island of Anglesey and the county of Wicklow, below the base of the Cambrian; that this Pre-Cambrian system is mainly of sedimentary origin, although igneous rocks are abundantly developed within its limits; that in short the "Monian System," as he proposes to call it, may be regarded "as an ordinary stratified system, perhaps fossiliferous on more than one horizon, and constituting the lowest member of the sedimentary series." Some suggestions are offered as to the correlation of various Pre-Cambrian rocks in other parts of the British Islands and in Belgium.

There are other prizes besides fair ladies that faint hearts fail to

win, and if Professor Blake does not achieve success I am sure he must feel with Pontius in Addison's Cato that he deserves it. It will probably be some years before any decisive verdict can be given as to the validity of Prof. Blake's views. The Pre-Cambrian rocks are confessedly one of the puzzles of modern geology, and whoever produces the clue to their history will have deserved well of geologists. Meantime there is this unquestionable advantage in Prof. Blake's position, that he has proposed a definite classification founded upon detailed observations, to be confirmed or disproved; and a definite classification, like a fixed position in war, simplifies both attack and defence.

The last of the longer papers published during the past year, though not equal in length to those already mentioned, is Professor A. H. Green's account of the Geology and Physical Geography of the Cape Colony. This paper, although founded on comparatively brief observations by the Author, has furnished a greatly needed epitome of the somewhat conflicting accounts given by previous writers, and for the first time has afforded a concise readable sketch of South-African geology by one who has been able to study the subject on the spot. Almost simultaneously with the appearance of Prof. Green's paper, an account by Dr. A. Schenk of "the Geological Development of South Africa" was published in Petermann's 'Mittheilungen,' and the classification adopted for the sedimentary formations is practically identical with Prof. Green's. The relations of that great system of South-African freshwater beds known to most Cape geologists by the name of Karoo (the term is applied only to a subdivision, by Prof. Green) to the underlying rocks are now fairly known, and the principal problem left is the relation between the Upper or Stormberg beds of the Karoo System and the Neocomian beds near Algoa Bay. I long since suggested the possibility, as in the precisely parallel series of conditions in India, of the two being in part, at all events, of contemporaneous origin.

The six papers mentioned occupy together 366 out of the 859 pages in the last year's Quarterly Journal (exclusive of the Proceedings). So far as my official experience of the Society's publications has extended, an equally large proportion of papers with an average length of 60 pages is unusual. But all the papers named, and the majority of them in an eminent degree, possess the character that my predecessor in this Chair at the last anniversary meeting of the Society laid down as justifying admission to the pages of the Journal.

Each represents "the result of carefully matured efforts," and some of the long papers I have quoted are remarkable for both clearness and conciseness.

Many of the other papers read before the Society and published in its Journal during the past year form valuable additions to our stock of knowledge, and it will not, I trust, be thought that my omission to mention them separately indicates an idea that they are inferior in value to those already cited. The longer papers have only been noticed in order to explain the additional bulk of the Society's Journal.

To English geologists generally, and especially to the Fellows of the Geological Society of London, the most interesting occurrence of the past year in connexion with our science has been the meeting of the International Geological Congress in this city. The history of that body is so well known that it is unnecessary for me to recapitulate it further than to remind you that the idea of a congress originated in the United States of America, at the Buffalo Meeting of the American Association for the Advancement of Science, in 1876, and that meetings of the Congress have since been held at Paris in 1878, Bologna in 1881, Berlin in 1885, and London in 1888.

But although the history of the congress itself has been related in some detail on more than one occasion, and recently by Prof. Prestwich in his opening address to the London Congress, I have met with no general account in English of the work done by the Congress and its committees. As I have had the advantage of taking part in the last three Congresses, and as I have attended most of the meetings of the International Committee for the unification of nomenclature since 1881, I may perhaps be able to give to the Fellows of this Society a few additional details, and thence to pass to the consideration of the question how far the action of the Congress hitherto has fulfilled the expectations of its founders.

In order to explain the subject to those who have not followed the history of the Congress closely, it will be necessary to go into some detail, and I must ask the Fellows of the Geological Society to bear in mind that in treating of a body mainly composed of European geologists, I occupy to some extent an alien position. At Bologna and at Berlin I attended the Congress as the official representative of the Geological Survey of India, and it is probable that on several questions English geologists hold views differing materially from

mine, whilst if the Reports of the British subcommittees on classification and nomenclature, and the Preface by Prof. Hughes, as presented to last year's Congress, faithfully represent the opinions of British geologists, I am obliged to dissent in some respects, as I will endeavour to explain hereafter.

I must also point out that several of the subjects to which I propose to refer have been treated with great clearness by Prof. G. K. Gilbert, in his able address read at New York in August 1887, to Section E of the American Association. In the majority of Prof. Gilbert's views I heartily agree, and like myself he regards the whole question from an extra-European standpoint.

There may be some difficulty in ascertaining what were the expectations of the geologists who originally suggested the idea of the Congress, and it may even be questioned whether the anticipations of all who assisted in the conception of that body were similar. The object of the Congress, as expressed in the resolution passed by the meeting of the American Association in 1876, was "for the purpose of getting together comparative collections, maps, and sections, and for the settling of many obscure points relating to geological classification and nomenclature" &c.; and this object was further defined and, so far as it is possible to judge, correctly defined at the Paris Meeting, where two International Committees were appointed, the one to deal with the unification of geological nomenclature, the other to propose a general system of coloration and signs for geological maps. A third committee, composed entirely of French members, was formed to consider the rules of palæontological and mineralogical nomenclature.

Of the subjects referred to the third committee one, and that the only one upon which a Report was presented and action was taken, was clearly beyond the scope of a Geological Congress. Palæontology, so far as the nomenclature is concerned, is purely a branch of biology, and palæontologists must adhere to the rules of nomenclature already established in zoology and botany.

Unfortunately zoological rules have not the same general acceptance as botanical; some zoologists are men with but little scientific training and imperfectly informed, and a few refuse to submit to any rules but those of their own caprice; consequently, as palæontology depends more upon zoological than on botanical nomenclature, there is much excuse for the offences against the rules of nomenclature in which it must be admitted that a few palæontologists indulge. This eccentricity in nomenclature on the part of a

few palæontologists doubtless led to the nomination of a committee and to the proposal of a set of rules which, after discussion and amendment, were adopted by the Bologna Congress. These rules differ in no important respect from the Stricklandian Code of the British Association, adopted by a large majority of English and by many foreign zoologists. Although, as has already been said, the subject is not one on which a congress of geologists is entitled to speak with authority, it is but right to say that the discussion at Bologna was left entirely in the hands of biologists, and was closer, more to the point, and more free from intervention by unqualified speakers, than any other discussions that took place at that meeting; in fact, coming at the conclusion of the week's proceedings, the sittings were only attended by those who were interested in the question. The conclusions are therefore well worthy of the attention of palæontologists. Amongst the most important are the exclusive acceptance of binomial terms and of the rules of Latin orthography, and the rejection of pre-Linnæan names. The rule that in future no palæontological specific names should be recognized as valid unless the species is figured as well as described, is also of great importance. One minor point, the recognition, under the name of "mutations," of geological varieties, or forms, in strata of different age, corresponding to the geographical varieties or races inhabiting different areas on the earth's surface, was a useful addition to palæontological terms.

The two more legitimate undertakings of the Bologna Congress have had a longer and more checkered history, and the story of the two has become much interwoven. Originally, as most geologists will remember, the two international committees, that for geological maps and that for nomenclature, were composed of a number of geologists, fourteen in the first case, fifteen in the second, each of whom represented his own country, and each of whom was expected to form, in that country, a national committee who should report to the general or international one. In the majority of cases such national committees were formed; but, as might be expected, several sent in no Reports, whilst the recommendations of others were received too late to be noticed in the General Report drawn up by the Secretary of each international committee and laid before the Congress.

The result was, that the General Report on the unification of map-coloration and signs, drawn up by Prof. Renevier, the Secretary of the International Committee, was founded on Reports from

Russia, Switzerland, France, Italy, Spain and Portugal (combined), and Belgium. No Reports had at that time been received from the committees formed in Germany, Austria, Great Britain, Scandinavia, or the United States. A Report from the English committee was received at the Bologna Congress, but was never before the members in a printed form. In short, of the fourteen countries represented on the international committee, the views of less than one half were in the hands of the Secretary when he drew up his General Report.

The question of map-coloration was, however, not only important but urgent. It is easy to look back now and to see that the Bologna Congress would have acted with greater wisdom had it postponed several of the questions on which a decision was taken; but it might fairly have been urged on the other hand that the crucial experiment of deciding scientific questions by the vote of a Congress was worth trying. Failure might have been foreseen; but as there were many believers in the wisdom of majorities, it was well that they should have an opportunity of being undeceived. At all events a proposal was made by Prof. Renevier to establish a colour-scale for geological maps, and it is possible that, had his proposals been adopted as they stood, the scale would have had a better chance of being generally accepted than has that employed in the map of Europe. As Professor Renevier's original scheme has been to a great extent forgotten, it may be as well to recall it.

The whole of the sedimentary rocks were classed in four "series" (this was, of course, before a different signification had been allotted to the term), archæic, palæozoic, mesozoic, and cænozoic; and each of the three latter was divided into three parts, to each of which a distinct tint was assigned. It was proposed that recent formations should be left white, and that the other sedimentary strata should be coloured as in the following list:—

Cænozoic.	Pliocene (including Pleistocene).	Pale sepia-yellow tinted orange.
	Miocene.	Brownish yellow (jaune chamois).
	Eocene.	Gamboge-yellow.
Mesozoic.	Cretaceous.	Green.
	Jurassic.	Blue.
	Trias.	Brick-red.
Palæozoic.	Permo-carboniferous.	Dark grey.
	Devonian.	Brown.
	Silurian (including Cambrian).	Violet.
Archæic.		Pink.

With regard to igneous rocks no recommendations were made,

the subject being regarded as not sufficiently studied. To one of the observations, however, which appears to me very important, I shall revert presently.

The Bologna Congress, it will be recollected, only decided upon the colours for Pre-Cambrian and Mesozoic rocks, and in doing so accepted Prof. Renevier's proposals, with the exception that, on his own recommendation, violet was adopted for Trias instead of brick-red, as had been proposed in the printed Report. Yellow tints were accepted for Tertiary systems, the higher beds to be represented by paler shades. The selection of hues for Palæozoic rocks, and the whole question of the coloration to be adopted for igneous formations, were referred to a committee appointed to arrange for the publication of a geological map of Europe.

There can be little doubt that the adoption, almost without discussion, of a different colour from that originally recommended for the Trias, was one of the greatest mistakes made by the Congress. The question should have been postponed. But, in point of fact, the question of the colours to be adopted for maps is one of which very few geologists have any wide experience, and it is consequently one which a congress of geologists is ill qualified to discuss.

Before passing away from Prof. Renevier's Report, it is as well to call attention to the circumstance that some very useful proposals were accepted unanimously by the Congress. These were :—(1) That different shades of a colour (or, as some express it, different tones of a hue) should be adopted for subdivisions of a system, the darkest shade being employed for the oldest subdivision; (2) That the lettering or literal notation for sedimentary rocks in general should be founded on the Latin alphabet, and that for igneous rocks on the Greek; (3) That each sedimentary system should be represented by a corresponding capital letter (*e. g.*, Jurassic by J), principal subdivisions of each system by the addition of a small initial letter (Portlandian by Jp), and the minor subdivisions by figures (Jp^1, Jp^2, &c.), the most ancient of the latter being represented by the lowest figure.

One other contribution to the question of map-coloration and signs was furnished by the essays sent in to the Congress to compete for the prize of 5000 francs (£200) offered by the King of Italy for the best memoir on these subjects. Although not one of the papers offered was deemed worthy of the full prize, three received awards and were published in the General Report of the Congress. All of

these—and especially the first, by M. Heim, of Zurich—contain useful suggestions.

The principal result of the whole discussion in the various Committees and in the Congress was, however, a resolution to publish, under the auspices of the Congress, a general geological map of Europe, on a scale of 1/1,500,000 (between 23 and 24 miles to the inch). It was arranged that the map should be prepared in Berlin under the direction of Prof. Beyrich and Mr. Hauchecorne, and the superintendence was entrusted to a Committee composed, in addition to the Directors and the Secretary (Prof. Renevier), of representatives of France, Italy, Russia, Austria, and Great Britain. This Committee has gradually become a kind of general referee, to which all difficulties and contested points have been left for solution.

The second international Committee already noticed—that for unification of geological nomenclature—should have been first mentioned, if the various subjects presented for consideration to the Bologna Congress were arranged in the order of their relative importance. I have, however, left it for the last, because it appears to me to be the subject in which the smallest result was obtained. The national Committees certainly began at the beginning, but for the most part they unfortunately ended their labours before arriving at any conclusions of scientific importance. It may fairly be doubted whether the American founders of the Congress contemplated laying down rules for the abstract terms to be applied to subdivisions of strata or of geological time. But congresses, unlike men, do change their minds when they cross the ocean, and the geological ideas of Paris were naturally very different from those of Buffalo. It was only natural that, the first two Congresses being held amongst people of the Latin races, terms should be treated with the precision essential in the language employed at the Congress. Another consideration to be borne in mind is, that a very large proportion of the leading geologists are engaged in teaching students, and are consequently inclined to attach great, possibly, in some cases, too great importance to an exact definition of the terms to be used.

It is scarcely necessary to recall to your recollection the geological terms agreed upon by the Bologna Congress—how the words *rock* and *formation* were defined; how it was resolved to divide the whole geological sequence of strata into *groups*, *systems*, *series*, *stages*, and "*assises*," and to employ as terms of duration equivalent to the first four the words *era*, *period*, *epoch*, and *age*. Unfortunately these terms, when adopted, were, by the nature of

the case, by no means rigorously defined, as it was impossible to say what was the relation in magnitude between, for instance, an epoch and a period; and although no difficulty was found in the division of all sedimentary rocks into great groups, and of geological time into great eras, the case was different when an attempt was made to divide the Palæozoic, Mesozoic, and Cænozoic groups or eras into systems or periods and series. This took place at a subsequent stage.

As in Paris, so in Bologna, the consideration of the further steps to be taken towards the establishment of uniformity in geological nomenclature was entrusted to a Committee composed, on this occasion, of 17 members, each representing a separate country. Meetings of this Committee, and of that for the geological map of Europe, were held together in September 1882 at Foix in the Pyrenees, and in August 1883 at Zurich in Switzerland. Both meetings, considering that the members of the Committees came for the most part from distant parts of Europe, were well attended. Of the 17 members of the Nomenclature Committee, 8 attended at Foix and 9 at Zurich; whilst of 8 members of the Committee for the preparation of a geological map of Europe, 5 were present on each occasion and took part in the discussions on nomenclature. These were mainly devoted to a classification of sedimentary and igneous rocks to be recommended to the Geological Congress of Berlin for adoption in the geological map of Europe. Questions relating to the coloration of the map were discussed by the Map Committee sitting by itself. Thus the whole question of unification, both of maps and of nomenclature proper, between the Bologna Congress of 1881 and the Berlin Congress of 1885 (and I think more real progress was made during this period than either before or after) was mainly limited to a thoroughly practical undertaking —the general classification of rocks, and the general system of coloration for adoption in the geological map of Europe. But although there were many advantages attending the practical form that the question of unification had taken, there was a serious disadvantage in the limitation of the discussion to Europe; and, in fact, this change involved a complete departure, unless I am much mistaken, from the intentions of the geologists by whom the original scheme of a congress was proposed.

A scheme of classification in groups, systems, and series was drawn up by a Committee of German geologists and submitted to the International Committee for approval. It may be useful to

quote side by side the original list and that which was finally accepted for the map:--

1. Gneiss and Protogine.	Gneiss.
2. Crystalline schists.	Crystalline schists.
3. Phyllites.	Azoic schists.
4. Cambrian.	Cambrian.
5. Lower Silurian.	Lower Silurian.
6. Upper Silurian.	Upper Silurian.
7. Lower Devonian.	Lower Devonian.
8. Middle Devonian.	Middle Devonian.
9. Upper Devonian.	Upper Devonian.
10. Lower Carboniferous.	Lower Carboniferous.
11. Upper Carboniferous.	Upper Carboniferous.
12. Lower Permian.	Permian.
13. Upper Permian.	
14. Lower Trias.	Lower Trias.
15. Middle Trias.	Middle Trias.
16. Upper Trias.	Upper Trias.
16′. Rhetian.	
17. Lower Jurassic.	Lower Jurassic.
18. Middle Jurassic.	Middle Jurassic.
19. Upper Jurassic.	Lower Jurassic.
20. Lower Cretaceous.	
20′. Gault.	Lower Cretaceous.
21. Upper Cretaceous.	Upper Cretaceous.
22. Eocene.	
22′. Flysch.	Eocene.
23. Oligocene.	Oligocene.
24. Miocene.	Miocene.
25. Pliocene.	Pliocene.
26. Diluvium.	Quaternary*.
27. Alluvium.	Modern.

On the classification of both sedimentary and plutonic formations many Reports were received from different National Committees. Several of these Reports contained replies to particular questions that had been circulated as to the classification of certain subdivisions, such as Gault and Rhætic, and the method of dealing with strata of indefinite or transitional age, such as the Flysch.

One very important proposition was brought before both meetings by Prof. Neumayr—that of the publication of a '*Nomenclator Palæontologicus*,' to contain a complete list, with full references to description, locality, and stratigraphical position, of all fossil species of animals and plants described up to the date of publication. The plan was approved by the Committee and received most favourably by the Congress of Berlin. Unfortunately, financial difficulties have hitherto prevented the scheme from being carried out. This is greatly to be regretted; it is difficult to name an undertaking that would

* From a note by Prof. Renevier, I learn that this term will be replaced in the published map by Pleistocene.

prove a greater benefit to palæontology, or one that would afford greater aid towards carrying out a uniform nomenclature.

The meeting of the Berlin Congress, which was originally to have been held in 1884, was postponed for a year, because it was thought by the Committee of Organization that the existence of cholera in Southern Europe in the first year might seriously interfere with the attendance of geologists. The Congress met at the end of September 1885, and was well attended, 166 German members and 86 of other nationalities being present. The number of inscribed members absent or present was 456.

It was evident from the very beginning that there was a marked contrast between the Berlin meeting and that of Bologna. How far this was due to a change of scene, and to the fact that the bulk of the assembly belonged in one case to the Latin and in the other to the Teutonic race, it is difficult to say. These cannot have been the sole causes of the differences, for most of the principal actors were unchanged, and the questions of nomenclature brought before the meeting were susceptible of treatment precisely similar to that employed at the Congress of Bologna. There can, however, be no doubt that a strong reaction had set in against the attempt to decide scientific questions by the vote of a majority; and in one instance, at least, on which opinions were greatly divided, the question as to whether the Permian should be regarded as a distinct system or united to the Carboniferous, the assembly deliberately abstained from voting. This question had already been discussed in the Nomenclature Committee at Zurich, and the numbers who voted on each side were equal.

It may here be pointed out that there is a great difference between a vote in a body consisting almost entirely of geologists familiar with the subject and of varying nationalities, as are those composing the Committee of Nomenclature, and a vote in a body of which the large majority belongs to one nationality and is composed to a great extent of those who have not paid particular attention to the details under discussion.

As a result of the meetings in Berlin, the proposals of the Map Committee for the classification of both sedimentary and igneous rocks were accepted with a few modifications. Two questions, however, were especially left over to the next Congress, which was appointed to be held in London last year. These questions were, the arrangement to be adopted for the Lower Palæozoic system or systems beneath the Devonian, and the classification of the Tertiary and (if admitted) Quaternary groups as a whole.

A considerable proportion of the time devoted to the work of the Congress at Berlin was occupied by the reading of papers on various geological subjects, several of them not relating to the questions before the Congress. Similar papers were sent to Bologna, but were not read, though they were inserted in the General Report.

The Reports from the British subcommittees on geological classification and nomenclature were presented at Berlin as a whole (some had been previously distributed), but without the preface subsequently added in the edition of 1888. These Reports differed materially from any that had previously been presented. They were far more detailed, and contained a history of each stratigraphical subdivision, and much information concerning the distribution and relations to each other of the various series, stages, and substages, so as to afford an epitome, in detail, of the stratigraphy of the sedimentary rocks occurring in Great Britain and Ireland. To the consideration of these Reports I shall return in the sequel.

The Committees for nomenclature and for the map of Europe were reappointed, with but trifling alterations, at Berlin; but the meetings between 1885 and 1888 were comparatively unimportant. Five members only of the Nomenclature Committee, out of the full number (20), met at Geneva in 1886, and eight at Manchester in 1887. Some of the conclusions arrived at by the first meeting, with regard to the modification of the Bologna decisions, met with disapproval at the second—a circumstance mainly due to the difficulty of adopting the same terms in all languages.

Finally, the fourth Congress was held last year in this city, and brought together a larger body of geologists than any previous meeting. The whole number of members was 830; of these 407 were present, 256 being from the British Isles and 151 from other countries. It must, however, be remembered that for the first time ladies were admitted. The number of well-known geologists was large; as an instance, it may be mentioned that 9 of the Society's Foreign Members and 13 Foreign Correspondents attended the meeting.

A fresh change took place in the method of procedure. At Bologna the reports drawn up by the Secretaries of the different Committees were discussed paragraph by paragraph, and accepted, modified, or rejected after a regular discussion. At Berlin certain parts of the Reports were accepted with little or no modification, others postponed. In London the Reports were almost ignored, and only three subjects were discussed; two of these were the questions already mentioned, relating to the classification of Lower Palæozoic and of

Post-Secondary rocks, and the third was a fresh subject of discussion—the origin and history of the crystalline schists—brought forward by the Organizing Committee and treated in a novel manner, by obtaining and printing beforehand dissertations from several specialists. On none of the subjects named was there any attempt to arrive at a decision: there was simply a discussion. It may be added that, whereas in one of the stratigraphical questions—the Cambrian and Silurian—there was some approach to a general agreement about the principal facts, and in the other a majority of the speakers were in favour of a particular view, the subject of the crystalline schists was left as chaotic as ever, or as, according to some of the disputants, were the conditions of the geological era when the schists themselves were formed. So far the discussion has scarcely tended towards unification of either nomenclature or views; the Neoneptunists still stand widely apart from the Neoplutonists; nor does there appear to be any prospect of agreement between those who pin their faith on gradual chemical or hydrothermic action and those who believe in violent movements of the earth's crust, or between those who contend that the 'Urgneiss' could only have been deposited in the Archæan era and in the depths of the primæval ocean, and those who urge that gneiss absolutely undistinguishable from its pre-Cambrian type has been formed in all geological epochs, and may be forming at the present day under favourable circumstances of heat and pressure.

The discussion on Tertiary classification, too, was almost confined to one point—the distinction of the Quaternary as an era apart from the Tertiary. The important question as to whether some better classification could not be adopted than that into Eocene, Oligocene, Miocene, and Pliocene, the limits of the different systems, and the desirability of subdivision, at all events in the case of the Eocene, were scarcely mentioned.

Besides the papers on crystalline schists and the second edition, with the preface, of the British Sub-Committees' reports on classification and nomenclature, there was presented to the London Congress a series of reports by American Sub-Committees on the classification of the sedimentary formations of North America. The importance of this work is due primarily to the fact that it does not refer to the portion of the world that has of necessity been accepted as the standard of comparison for the geological scale; and, secondly, to the circumstance that much of the information has been accumulated very recently, and has not found its way into text-books.

A summary of the conclusions, drawn up by Dr. Persifor Frazer and translated by Prof. Dewalque, was circulated separately. It is to be regretted that a similar *résumé* of the reports of the British Sub-Committees was not prepared.

The history of the Congress, it will thus be seen, up to the present time, is the history of an undertaking begun with great, if somewhat misdirected, zeal and energy, and gradually descending in its aims, till, from attempting to establish a universal geological language, and to regulate the coloration, signs, and scale of geological maps in general, it has contented itself with supervising the issue of a map of Europe in which both classification and colour are admittedly tentative; whilst, instead of deciding points of primary importance by votes, it discusses questions, sometimes of secondary importance, without attempting to lay down any law. In passing from Bologna to Berlin, and from Berlin to London, there has certainly been a tendency on the part of the Congress to abdicate its early pretensions, to collect information, and to cease from issuing edicts. It now remains to be seen what will be the effects of the meeting of 1891 in Philadelphia; whether the Congress will rise again, Antæus-like, in its pristine vigour, from contact with its native soil; or whether it will resolve itself into the intercalation of a little mild academic discussion between much more largely developed schemes of social amusement—a fashion not unknown in other scientific meetings, especially when ladies are admitted.

In considering how far the institution of a triennial Congress has hitherto fulfilled the expectations of its founders, it becomes necessary to discuss the apparent results hitherto obtained. These are:—

1. The terms adopted at Bologna;
2. The subdivisions and colouring adopted on the geological map of Europe;
3. The various Reports from different national and international Committees, and all other documents published in connexion with the Congress.
4. The exhibition of maps and specimens.

On each of these a few words may be added.

1. The various terms for strata and time adopted at Bologna have been accepted to a considerable extent abroad, but have as yet found but small favour with English geologists. Even in the Reports of the British Sub-Committees on classification and nomen-

clature there is a complete disregard of all restrictions upon the use of terms.

It is quite true that the number of kinds of subdivisions made in both stratigraphy and time by the Bologna Congress was rather greater than was necessary, and that the restriction of the two words *group* and *series* to particular subdivisions in the scale renders it very difficult to write upon stratigraphy in English, owing to the poverty of the language in geological terms and to the fact that these two words have been used for every kind of subdivision indiscriminately. The use of *group* for so large a division as Palæozoic and Mesozoic is quite opposed to our habit, as the word has hitherto been more frequently used in the sense of the French *étage* than for any larger division. The proposal repeatedly made by the French and other Committees to transpose the words group and series, and to apply the latter to great divisions like Palæozoic, and the former to divisions of the third order, would be an improvement; but it would be far preferable to diminish the number of subdivisions, and to eliminate both words, group and series, from the restricted list—to revert, in fact, to the original proposal of the English Committee in this respect. Professor Hughes calls attention to a suggestion of Professor Sedgwick's, to use *class* for the largest divisions. I had made the same suggestion myself, in ignorance of Professor Sedgwick's employment of the word, when writing on the subject for the International Committee meeting in Geneva; and I think if English geologists would agree to employ the term *class*, or, as Professor Cope has suggested, *realm*, as the English equivalent of *group*, and to omit *series* and *assise* altogether, as unnecessary, we should have three words left—class or realm, system, and stage—two of which are additions to our very poor list of English terms. I cannot agree with Prof. Hughes in objecting to the word *stage* because it is not exactly the equivalent of *étage*; it appears to me a great advantage to have an English word to fit precisely where a term is peculiarly wanted. I feel sure that if English geologists will condescend to try the term they will find it extremely useful. If intermediate or inferior subdivisional names are needed, the terms subclass, subsystem, and substage might be employed.

The distinction drawn at Bologna between stratification- and time-words is one of very great importance, and I believe English writers would do wisely and would aid in the progress of the science by adopting the reformed nomenclature. Until there are clear ideas on the subject, and until the distinction of the two categories

is rightly appreciated, there is but little hope of any sound classification.

There is, however, one of the time-words adopted at Bologna that must in English be left for unrestricted use, for the simple reason that we cannot replace it. This is *age.* It is impossible to avoid writing of strata and fossils as of Palæozoic age, of Jurassic age, &c.; and although this might be done without ceasing to use the term as the time equivalent of *stage*, it would be better to replace the word by another, or if the number of subdivisional terms is diminished, to omit *age* altogether. I would suggest to British geologists for consideration some such scheme as the following:—

Stratification.	*Time.*	*Example.*
Class.	Era.	Palæozoic.
System.	Period.	Jurassic.
Stage.	Epoch.	Oxford Clay (Oxfordian).

If this or some corresponding plan were adopted there would be no necessity for the adoption of the word *terrane* proposed by Prof. Gilbert to be used for a stratigraphical subdivision of any magnitude, though the language would gain by the employment of such a term.

It must not be forgotten that if, as already noticed, the Bologna Congress failed to define the subdivisions that it sanctioned, the failure depended very much on the inherent impossibility of the task. There is absolutely no scale by which periods or epochs can be measured ; all that can be done is to enumerate certain divisions of geological time as represented by particular strata and enact that such subdivisions shall rank as periods or epochs. As the stratigraphical divisions are utterly dissimilar in different countries, the determination for one region will afford but little aid in another. All that can be done, in short, is, as has been admirably pointed out by Professor Gilbert, to adopt an admittedly arbitrary and empirical scale of systems for the sedimentary rocks of Western Europe, as being the best known, and to employ this scale for comparison in other countries.

The classification of the geological sequence has, in fact, been founded on no recognized system, but has grown up gradually. Just as in a newly discovered country, or in a barbarous continent in process of annexation by more civilized peoples, a colony has been founded here and there, until by irregular growth, depending for its progress on various circumstances, the borders of the different

territories have come into contact and require to be defined. If good natural barriers, such as a mountain-range or a broad river intervene, these have generally been taken as frontiers; but if not, frequently after much dispute, some less defined line has been adopted. Substitute for colonies strata and for the physical boundaries of rivers and mountains the equally well-marked limits corresponding to petrological change, often accompanied by unconformity, and the history of the repartition of the stratigraphical sequence into systems and stages corresponds to the subdivision of geographical areas into states. The story is a story of haphazard, in which scientific induction has played a subordinate part, and the idea of rendering the divisions equal has probably never occurred to any one.

There is, however, this difference between countries and strata. The mapping out of the former covers the whole area, whilst the latter in any and every country can only represent a certain portion, probably a very small portion, of geological time. The gaps that are unrepresented are an unknown quantity, but are undoubtedly in any given area in excess of that portion of the scale that is represented by strata. Therefore even if the thickness of strata in any subdivision were directly proportional to the duration of time occupied in the formation of that subdivision—in other words, if the thickness of a system varied directly with the duration of the corresponding period, which it most certainly does not, the duration of the corresponding division on the time-scale would still be unknown, as the time corresponding to the breaks in the sequence is undeterminable.

2. Under these circumstances, and seeing that anything like an equalized scale is hopeless at present, there is a fair reason for accepting, as has been done in the map of Europe, those periods that are best known. In the Mesozoic era, for instance, in which the relations of the periods are simpler than in the Cænozoic or Palæozoic, there can be very little question that a division of both Cretaceous and Jurassic into two would produce periods much more nearly equal to the Trias in palæontological importance (the only approach to a time-test that we possess) than are the great Cretaceous and Jurassic periods as at present usually adopted. This subdivision of the Mesozoic era into five periods, Cretaceous, Infra-cretaceous, Oolitic, Liassic, and Triassic, has been adopted by several geologists, amongst others by Renevier and by De Lapparent

in his 'Traité de Géologie.' It would, however, have required a much more general agreement than exists amongst European geologists to have justified so marked an innovation in the map of Europe. The same remark applies to the acceptance of the Permian as a distinct subdivision, although it is not only inferior in importance to the Trias, but is palæontologically an integral part of the Carboniferous. To reduce such periods as Cretaceous, Jurassic, Silurian, and Cambrian into a form in which they would represent, even approximately, divisions of the same duration as Pleistocene, Pliocene, and Permian, would involve a complete rearrangement of the whole geological succession. Before an attempt is made at such a rearrangement it is desirable that a larger area than Western Europe should be selected for the field of experiment.

When, however, we pass from the systems of the map to their subdivisions, it is difficult to avoid feeling some degree of doubt as to whether a more equable arrangement might not have been adopted, even for European rocks. The Trias is divided into three series, the far more important Cretaceous system into only two, and the Eocene and Cambrian are undivided. It is impossible to avoid regretting that the relative local importance of particular subdivisions has led to the raising of a comparatively unimportant stage like the Muschelkalk to a rank equal to that of Neocomian and Gault combined, or to that of the Lias, together with the Rhætic in many localities, or to that of the whole Cambrian. The fact, of course, is that in this case deference has been paid to a time-honoured classification peculiar to part of Germany and a small area in France. This is an illustration of the evil produced by merely local classifications and by the misleading name under which the Triassic system is known, a name derived from the local subdivision of the system into three well-marked stages, two of which are, in the main, subaërial, fluviatile, or lacustrine, and the third alone marine. The latter, moreover, contained a peculiar local fauna which probably inhabited an inland sea, and differed materially from the true marine Triassic fauna which has now been traced from the Alps and Spitzbergen to Chili and New Zealand. In short the so-called typical Trias is altogether an exceptional and abnormal system, and useless for purposes of comparison.

The coloration of the sedimentary rocks in the map of Europe has the very common defect that the colours are in large measure too dark and too opaque; but it is understood that this will be altered to some extent. The system of colours does not give satis-

faction in America, nor, so far as is known, elsewhere. It is to be regretted that violet was not kept for Silurian, as proposed by several of the National Committees, and brick-red for Trias, as advocated by almost all; and no doubt the change in this respect has done something to render the system adopted unsatisfactory. Violet between grey (Carboniferous) and blue (Jurassic) is open to the objection that the paler shades are not sufficiently easy to distinguish, whilst brick-red (impure orange) is distinct in all shades.

It may, indeed, be doubted whether any scheme of coloration could be devised that is free from objection. Much has been said of the advantage of a system based upon the solar spectrum, and, indeed, in the plan adopted there are some lingering traces of a spectral system, blue, green, and yellow succeeding each other in the Upper Mesozoic and Cænozoic groups. Prof. Gilbert has suggested a very ingenious and apparently simple plan of dividing the spectrum into hues defined by their wave-lengths or, which comes to the same, by their position on the Kirchhoff scale. He is of opinion that from fifteen to twenty sufficiently distinct hues can be thus selected, and these, with the purples which are not contained in the spectrum, would suffice for the different periods. He would then allot brown to igneous rocks.

This plan has, I believe, one fatal objection. If the adjacent spectral hues are in contact on the map, even though the full tones or shades be distinct, the paler tones will not be so. The only remedy would be to alternate colours from different parts of the spectrum, and then the orderliness of the plan, its principal recommendation, would disappear.

The fact is that the distinctness of colours adjacent to each other is an essential requirement of any efficient system, though but few of those who have treated of map-coloration in connexion with the Congress have referred to this important point. It must be remembered that all hues in contact should remain sufficiently distinct after a certain amount of fading from exposure, and that all should be easily distinguished by artificial light.

The classification and coloration of the igneous rocks on the map of Europe is very unsatisfactory, and I shall probably have the hearty concurrence of English geologists in general in condemning the system proposed as impracticable. In the first place, as was pointed out by Prof. Renevier some years ago, it is illogical to arrange the sedimentary rocks entirely by their geological date, irrespective of petrological character, and the igneous rocks entirely

by petrological characters irrespective of their date of origin. No doubt, in the map of Europe, a petrological distinction is made which is supposed to be connected with geological age, when diabase and melaphyre are distinguished from basalts, and porphyry from trachyte and its allies; but the supposed connexion between geological antiquity and mineral characters in the case of these rocks is held by the best English petrologists, and on sound evidence, to be erroneous. It is difficult to see why the igneous rocks of which the period is known cannot be represented by the colour of the period to which they belong, but deep and opaque, the petrological character, if it is considered essential, being represented by the monogram; whilst some simple convention might be used for outbursts of unknown period. Or all igneous rocks might be represented by one conspicuous colour, the monogram serving to distinguish the kind of rock. It is difficult to understand why in a map in which no colour-distinction is drawn between limestone and sandstone, chalk and slate, rock-salt and coal, clay and iron-ore, quartzite and gneiss, except that due to geological age, it is essential to distinguish by colour between granite and porphyry, melaphyre and basalts, peridotite and serpentine, although several of these are so inextricably mixed in places that their outcrops could not be disentangled on a map with a scale 100 times larger than that of the map of Europe. It is reasonable to suppose that the assignment of one colour to the lavas of active or extinct volcanoes, another to the ashes and scoriæ, and a third to "stratified tuffs," was proposed by geologists who had not much personal experience of volcanoes of either kind. Really the proposal to map the three apart on a scale of 24 miles to the inch sounds like a joke.

But even accepting the fact that what has been done hitherto must be done in the future, and that the geologists of Western Europe insist on colouring the igneous rocks on a system radically distinct from that employed for sedimentary formations, it is still difficult to understand the advantages of so many subdivisions as have been adopted in the map of Europe, or to understand how it will be possible to colour the numerous outcrops of igneous rocks that are intermediate between two of the ill-defined groups established, or composed of two kinds belonging each to a separate group. Surely if petrological characters must be the guide in coloration, some simple division, as into basic and acid rocks, would suffice. There would be difficulty even in this, as when trachytic lavas are interstratified with basaltic, or when a rock occurs con-

taining a percentage of silica on the artificial limit between acid and basic rocks; but all difficulties of this kind increase in geometrical ratio with the numbers of groups into which an attempt is made to classify the various rocks.

Whilst thus criticizing some of the details of the map, it would be unfair not to recognize the fact that the Directors have worked under considerable difficulties, having, in fact, been obliged to act very largely on their own responsibility. In all probability no map of Europe would have been produced had not Prof. Beyrich and Mr. Hauchecorne undertaken the direction of the work, and all geologists owe a debt of gratitude to those gentlemen. Although it is not likely that this map will determine the questions of coloration and nomenclature, it will doubtless contribute largely to their being settled.

3. It is probable that the published accounts of the different meetings of the Congress form the most important contribution made by it to Geological Science. The Reports from the various National Committees are naturally very unequal in importance, but many of them are excellent, and all of them suggestive.

In this connexion it will be, I hope, not impertinent if I call attention to the British Sub-Committees' Reports. In the Preface these Reports are held up as a model on which those of other countries should be framed and it is claimed that "the greatest advance in the work proposed to be done has, so far, been made in practical England." A claim of this kind invites criticism, and as the writer is the President of the National Committee, and therefore the representative of English geology, his views are doubtless those of many British geologists. As already noticed, these Reports contain an epitome of the detailed stratigraphy of the British Isles, arranged in convenient divisions, the Report on each division being written by one or two authors. The history of the various names employed for the different subdivisions in which the strata were classed is given, and the views of the principal observers as to the correlation and classification of the beds in various parts of the country are recorded. There is naturally some inequality; slight differences are, however, to be expected, and taking the work as a whole, there appears to be every reason to believe that the authors have carried out very thoroughly that which they undertook, viz. to give the history, synonymy, and detailed classification of British sedimentary rocks.

But the question which has occurred to me, and, I think, probably to some of the foreign geologists who have had occasion to consult the 178 pages of details, is this:—In what way does all this work contribute to the Unification of Geological Nomenclature? It is easy to see that the Reports under consideration will facilitate the work of those who have to fit the geology of the British Isles to the map of Europe, though even for this purpose some knowledge of the correlation between British and continental strata is necessary. Undoubtedly, too, the information given in these Reports will be most useful to compilers of general works on Geology, whilst to all British geologists it will be of advantage to have within reasonable compass so general an account of the British stratified rocks. But unless I am much mistaken, the object supposed to be in view is the establishment of a general classification for the strata of the world, or at all events of Europe, and for this the careful and elaborate details upon which so much labour has been expended by the reporters appear superfluous. As the British strata have been very largely taken as types, especially in the Cretaceous, Jurassic, Silurian, and Cambrian systems, the history of the names is important; but a general table of the beds from top to bottom, arranged according to the latest information available, would have been sufficient for purposes of comparison with the strata of other countries. If comparison with the systems and stages of distant countries was contemplated, far more complete information as to palæontology should have been given. In short, I venture, with some diffidence, to suggest that the work may produce upon those who, like myself, approach the question from a foreign point of view, the impression that there is too much of data that are of little or no use except to local geologists, and too little of the information that would be useful for comparison with the geology of other countries.

It may be assumed that the principles upon which the work has been compiled are those stated in Professor Hughes's Preface. In this he urges the adoption of a natural, as opposed to an artificial system, and points out that the characters of greatest value in the classification of the sedimentary rocks are obviously those which indicate changes of condition affecting sedimentation and life. He then proceeds to explain what he means by an artificial system; and here I would venture to suggest that a different view may be taken of the matter.

If Professor Hughes had confined himself to urging that in classifying the rocks of any limited region, or even of a country the

size of the British Isles, the breaks in stratigraphy, whether petrological or palæontological, must first receive attention, and that such breaks must be accepted as limits of the subdivisions in which the strata are arranged,—if, in short, it were urged that a local classification must depend upon different considerations from those deemed of primary importance in a general classification, his views would necessarily deserve acceptance, since he would only recapitulate the facts upon which all local classifications have been based. But, if I understand him rightly, this is not the position he takes. He contends that palæontological classification, and especially a classification by marine or "pelagic" types of life, is artificial, and that the only natural classification is founded upon local breaks in sedimentation or in life. I am unable to agree with any of the above contentions, and I must say that I shall be very much surprised if in these points Prof. Hughes represents the views of British geologists in general. Indeed, in some of the Reports that follow his preface, for instance in the remarks by Messrs. Jukes-Browne and Topley on the Purbeck beds (p. 73), I find precisely the opinions put forward with regard to the part played by marine faunas in classification that I have hitherto understood to be generally held amongst geologists throughout the world.

There can be no question that all breaks in stratigraphy are local, and that such breaks are or may be represented elsewhere by beds. Moreover local breaks are very often misleading, because the amount of change, and especially of unconformity, is not proportionate to the lapse of time, but depends on phenomena often confined to a limited area, and which may have been of no great duration or real importance. Thus the great break and unconformity between the Coal-measures and Permian in Great Britain is shown to be representative of but little lapse of time by the fact that no change of any importance took place in the marine fauna, the alteration in which between the Carboniferous Limestone that preceded the Coal-measures, and the Permian magnesian limestone, is actually less than that between Devonian and Carboniferous, which are not separated by any important stratigraphical break. If any great lapse of time, or any widespread physical changes, corresponded to the local break between Carboniferous and Permian in England, it may reasonably be assumed that a great change in marine life would have taken place in the interval.

The argument to which Professor Hughes naturally refers, that identity of marine fossils in distant localities does not prove

synchronism, but rather suggests that the strata were not of contemporaneous origin, as time would be needed for migration, is one on which perhaps too much stress is laid by English geologists. In the course probably of a geological age, certainly of a geological period, there must be ample time for the migration of marine forms, whether pelagic or littoral, throughout all seas that are in connexion. If the marine fauna of the present day be examined, it will be found that many marine genera, both of vertebrata and invertebrata, are of world-wide range, and that still more are distributed in wide belts stretching round the world. This will be found to be the case with littoral quite as much as with pelagic forms, though there may be more specific variety in the former. Still a host of littoral genera, such as, amongst the Mollusca, *Littorina*, *Patella*, *Purpura*, *Nassa*, *Natica*, *Chiton*, *Mytilus*, *Cardium*, *Solen*, *Mactra*, and *Pholas*, are found on almost every coast in the world.

Now the identification of the age, or still more of the period, to which a fossil fauna should be referred does not necessarily depend upon all or any of the species being identical with those in a known deposit. Complete identity, when the deposits are far apart, seldom or never occurs except amongst pelagic types, the occurrence of a few identical or allied species, and a similar association of particular genera and subgenera, being the evidence usually adduced in favour of contemporaneous origin. Thus the faunas of marine deposits in America or Asia compared with those of the same geological age in Europe will be found to exhibit much the same resemblance to each other as do the faunas of the present seas taken from two equally distant parts of the Earth's surface. There is one possible exception to be borne in mind. It is probable, though not absolutely proved, that the present temperature of the Arctic regions is much lower than it has been on an average in past times—it is certainly lower than it was in some epochs—and that consequently not only the Arctic fauna, but also that continuation of the Arctic fauna which extends from pole to pole at the bottom of the deep sea differs more from the tropical and subtropical faunas than has been the case throughout the greater portion of geological time.

Still, despite this disadvantage, if the living marine fauna of any part of the ocean, including Vertebrata, Mollusca, Crustacea, Echinodermata, Foraminifera, &c., is compared with that of the early Tertiaries (Oligocene or Eocene), a great generic difference will be

found, fairly comparable to the distinction between Eocene and Cretaceous life. Comparison of the recent forms with Miocene types would show a distinct, but less well-marked, difference, and if recent and Pliocene faunas were compared, the distinction would be still smaller; but all the newer Tertiaries, commencing with the Miocene, form but one period with recent times, if the marine faunas are taken as the test; and it may be doubted whether the Pliocene could even be separated as a different geological age from the Recent.

So far I have merely ventured to express a different opinion from Professor Hughes. But on one point I think he is mistaken, and it is very important to call attention to the mistake, because the idea expressed may be widely spread amongst geologists. Professor Hughes says that "we are every day reminded by the work of specialists that the result of applying the botanical measure often differs considerably from that obtained in the present state of our knowledge from a consideration of the included animal remains.... This does not destroy our confidence in the value of palæontological evidence. We have no doubt that when all the fossil evidence, botanical and zoological, has been adduced it will be consistent."

Now I think that it will be found that the real contrast in the indication of palæontological age is not between botany and zoology, but between land or freshwater faunas and floras on the one hand, and marine faunas on the other. So far as is known, there is not a single well-marked case of the inversion of marine faunas, the only instance of any importance ever brought forward, that of Barrande's colonies, in which an Upper Silurian fauna was supposed to occur in beds intercalated amongst others with Lower Silurian types, having, I believe, been conclusively shown to be founded on a mistake in observation. This fact, the absence of all evidence of inversion, is of itself a proof that similarity of pelagic forms does signify practical synchronism; because if the similarity implied difference of time due to migration, some cases of inversion must occur*. But in land faunas and floras cases of inversion and of the association of types characteristic of different epochs and even periods in the same beds

* This may be shown thus: let there be two areas, one inhabited by a fauna A, the other by another fauna B. Now let A migrate into the area occupied by B, and *vice versâ*. We should then find in the one area B fauna in the upper bed, A in the lower; in the other area A in the upper, B in the lower. Of course the relations would in all probability be more complicated, but the results would be the same.

are numerous. Thus we find the Miocene mammals of the Pikermi beds resting upon Pliocene marine strata in Greece; a Middle Jurassic flora in beds interstratified with others containing a Carboniferous marine fauna in New South Wales; similar strata with Middle Jurassic plants in India overlain by beds with Triassic, and by others with Rhætic plants, and these, again, succeeded by others with Triassic reptiles; Middle Jurassic plants intercalated between Neocomian and Tithonian beds in Cutch, and Tertiary plants associated in the same strata with Cretaceous Dinosaurs in the Laramie beds of North America. Such cases are explained by the circumstance that the distribution of the land fauna and flora at the present day is very much less uniform than that of the sea; that a terrestrial zoological genus of anything like world-wide distribution scarcely exists; and that even under the same parallels of latitude, amongst the terrestrial genera in America, Africa, and Australia, for instance, only a small percentage are the same, whilst many of the families and some of the orders are peculiar, all testifying to isolation from great antiquity.

There is, moreover, evidence that the recent fauna is sometimes descended from that which inhabited the tract in Tertiary times, sometimes from an immigrant fauna. Thus, as has been pointed out by Prof. Huxley, by Mr. Wallace, and others, the Mammalian fauna of Central and Southern Africa at the present day is descended from the Miocene (and Pliocene) life of Europe. If a bed were found in Southern Africa containing bones of giraffes and certain antelopes, naturalists only acquainted with European fossil faunas would class it as Miocene (or Pliocene), although it might rest upon strata with Pleistocene marine fossils.

Again, the recent Mammalian fauna of Australia and New Guinea is Mesozoic rather than Tertiary in its affinities. Nevertheless it is by no means improbable that the gigantic migrations produced by the cold of the Pleistocene epoch have rendered the Earth's terrestrial fauna and flora more uniform than was the case in past times; and it may be doubted if anywhere in the world at present there is so wonderful a contrast as that between the Carboniferous flora of Australia and the contemporaneous vegetation of Europe and North America.

It may be possible, when far more is known than is the case at present, to make out the history of the terrestrial faunas and floras of different subdivisions of the Earth's surface. But when the history is known, it is safe to predict, from the little already ascertained, that the tale of the land will not coincide with that of the sea, nor will the story of one terrestrial region be the same as that

of another. So far as our present information goes, we must, I believe, in mapping out geological periods and epochs, rely upon what Professor Huxley has called "sea-reckoning" alone.

4. There is one other feature of each Congress that has hitherto produced a sensibly beneficial effect; this is the exhibition of maps and specimens. This was one of the objects for which the Congress was originally constituted, and one the usefulness of which is unquestionable. At every meeting many geological maps from various countries have been exhibited, and have afforded an opportunity for the comparison of different systems of coloration, signs, &c. Many specimens of general scientific interest, too, have been brought to the notice of those present at the Congress; for instance, the Trilobites and Corals in crystalline schist from Norway, exhibited by Prof. Reusch in Berlin, the Belemnites in metamorphic rock from the Alps, shown by Prof. Heim, and the striated fragments (apparently showing glacial markings) from Carboniferous beds in the Punjab, exhibited by Mr. Oldham in London.

Comparing the performance of the Congress with the objects of its founders, it may briefly be said that the Congress has succeeded, to a certain extent, in getting together comparative collections, maps, and sections, but that it has not settled many obscure points relating to geological classification and nomenclature.

There remains one other subject to consider, the probable effect of the Congress upon the progress of Geological Science. This, I believe, has already been much greater than is commonly supposed, but in a direction quite apart from that leading to the geological millennium which was anticipated when we should have achieved a uniform geological nomenclature and system of representation by maps. The principal result so far has been the bringing together many geologists from different countries, and affording them an opportunity of becoming personally known to each other. The effect upon the diffusion of geological research, and the consequent reaction of one observer's discoveries upon another who is inquiring into a cognate subject in a distant country, is very great, and is likely to increase. By this means a much greater step will be made towards unification of nomenclature and maps than would result from the appeal to a majority at a Congress.

Another advantage is the bringing together and publishing the

views of different men who have paid attention to particular points connected with the progress of the science. When the views differ so widely as in the case of the crystalline schists, but small progress towards unanimity can be expected; whereas in another matter discussed at the London Congress, the division of the Lower Palæozoic rocks, there was a general agreement as to the partition into three of the Cambrian and Silurian complex, and this really settles the question; for it is evident that on palæontological grounds the lowest division or Cambrian must be classed apart from the other two. There can be no doubt, too, that the wide dissemination of the discussion on a geological question has a good effect, as even if it leads to no results, it produces thought and study in fresh directions.

I have already expressed my grave doubt as to whether a vote in any Congress can be accepted as the opinion of a qualified majority, and I am inclined to believe that many, perhaps all, of the questions proposed for solution are beyond the scientific range of a considerable proportion of the members. The first objection to the method of voting was that the natives of the country in which the Congress was held outnumbered all others present, and thus, that foreigners, many of whom were representative men, and some of whom were especially sent to represent scientific bodies in their own countries, were hopelessly outvoted. An arrangement adopted at the London Congress will obviate this difficulty in part, it having been decided that whenever a vote is taken the members belonging to the country where the Congress is held and the foreigners shall vote separately, and unless there is a majority in each class of members the vote shall be null and void. With this improvement a vote may occasionally be taken, but its value, unless the agreement is almost unanimous, will be small, unless the personal composition of the minority is known.

Membership of the Congress in Bologna was limited to authors of memoirs on geology, palæontology, or mining, university professors, teachers of natural history in public schools and technical institutes, doctors of natural science and mining engineers; but still the opinions of theological, classical, mathematical, or chemical professors on geological nomenclature, or of mining engineers on the colours to be used in geological maps, could scarcely be considered as authoritative. Where, as in London, the qualification for membership began and ended with the payment of ten shillings, the idea of deciding scientific questions by a majority would have been

absurd. As in the case of the British Association, the methods of which are being largely followed by the Geological Congress, the latter must, if voting becomes necessary, select an inner body or committee, and even in a body of experts it must be borne in mind that no one is equally informed in all branches. The opinion of a geologist who has devoted his life to Palæozoic strata would not be of much value if it were sought to draw a line between Eocene and Miocene, and he would be even less competent to decide on questions of petrological nomenclature, whilst a petrologist with a world-wide reputation may never in his life have had to colour a geological map or have thought over the principles involved.

One good effect the Congress has had already. It has set itself steadily against the adoption and even the discussion of sundry visionary and impracticable suggestions, and the number of these has steadily decreased. An admirable example has been set in the case of what are termed by many geologists homophonic terminations. It was proposed that all names of systems should end in -ic, series in -ian, &c. The proposal found no favour with Teutonic-speaking peoples, and was therefore unsuited for a Congress in which various languages were represented; but it happened to be a favourite project with some of the members of the Nomenclature Committee, and it has consequently been brought forward prominently in the Report presented to three Congresses in succession. It is not, I think, likely to reappear.

The length to which the preceding remarks on the Geological Congress and its labours have extended has left me no time to dilate on the other geological events of the past year. There are but few to which it is necessary to refer. The publication of the first part of the 'Geological Record' for the years 1880–1884 should not, however, be passed over without notice. A second volume has yet to appear. To have even an instalment is unquestionably a gain, and geologists are under many obligations to Mr. Topley and Mr. Sherborn for having rescued the work from complete collapse; but still it is a matter for serious regret that the annual volumes should have been interrupted.

It is as unnecessary to prove the importance to all working geologists of having a Geological Record as it is to argue that the best language for the purpose is English. But the labour involved in preparing and editing a work of the kind is excessive, and the difficulty of establishing a permanent publication very great indeed.

The much older 'Zoological Record' has only been saved from coming to an end through the intervention of the Zoological Society; and if the funds of this Society would allow, there are few purposes to which they could be applied better than to the maintenance of a Record of Geological Literature.

The unfortunate failure for the moment of Prof. Neumayr's admirable proposition to prepare and publish a new 'Nomenclator Palæontologicus,' and the tardy appearance of the 'Geological Record' in a curtailed form, are unwelcome announcements. It is satisfactory, therefore, to have a more promising event to chronicle. The appearance of the first volume of Mr. Etheridge's long promised 'Fossils of the British Islands' during the past year affords an important contribution to works of the class to which the two above named belong. If Mr. Etheridge's work is as exhaustive as, from the time and labour spent upon it, we are entitled to hope that it will prove, it will be a most valuable aid to palæontologists, and will facilitate the preparation of that general list of all described fossils which is at present one of the greatest desiderata in geological science.

February 20, 1889.

W. T. Blanford, LL.D., F.R.S., President, in the Chair.

Upfield Green, Esq., Liebenheim, Watford, Hertfordshire; Wintour Frederick Gwinnell, Esq., Argyle Villas, White Hill, Gravesend; John Charles Mackay, Esq., Assoc. M. Inst. C.E., Stow Park, Newport, Monmouthshire; and George Synge, Esq., 3 Harrington Mansions, Queen's Gate, S.W., were elected Fellows of the Society.

The List of Donations to the Library was read.

Visitors having withdrawn, the President, in accordance with Section XI. Art. 8 of the Bye-Laws, read, for the second time, the notices of motion relating to the proposed alterations in the Bye-Laws, signed by Mr. T. V. Holmes and twelve other Fellows, and by Dr. G. J. Hinde and nine other Fellows; and also, for the first time, some proposed emendations to the motion of the Council drafted by the Council and signed by the Chairman, a notice signed by Mr. J. Hopkinson and five other Fellows of the Society, and one signed by Mr. R. Lydekker and sixteen other Fellows of the Society.

The President further announced that a Special General Meeting, for the consideration of the Bye-Laws, would be called for Friday, March 15, 1889, at 4.30 p.m.

The following communications were read:—

1. "On the Cotteswold, Midford, and Yeovil Sands, and the division between Lias and Oolite." By S. S. Buckman, Esq., F.G.S.

2. "On some Nodular Felstones of the Lleyn Peninsula." By Miss Catherine A. Raisin, B.Sc. (Communicated by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.)

3. "On the Action of Pure Water, and of Water saturated with Carbonic-acid Gas, on the Minerals of the Mica Family." By Alexander Johnstone, Esq., F.G.S.

The following specimens were exhibited:—

Specimens from South Caernarvon, with microscopic sections, exhibited by Miss C. A. Raisin, B.Sc., in illustration of her paper on Nodular Felstones.

Specimens of Pyromerides and other allied rocks, from Boulay Bay, Jersey, exhibited by Prof. T. G. Bonney, D.Sc., F.R.S., F.G.S.

Photograph of a group of Members of the International Geological Congress taken during the visit to North Wales, September 1888, exhibited by Dr. H. Hicks, F.R.S., F.G.S.

March 6, 1889.

W. T. Blanford, LL.D., F.R.S., President, in the Chair.

David Yewdall Cliff, Esq., Nesbit Hall, Fulneck, near Leeds; Edward Aurelian Ridsdale, Esq., Assoc. Roy. School of Mines, Rottingdean, Sussex, and 3 Montague Street, W.C.; and Bernard Henry Woodward, Esq., 80 Petherton Road, Highbury New Park, N., were elected Fellows of the Society.

The List of Donations to the Library was read.

A photograph of a group of Members of the International Geological Congress taken during the visit to North Wales, September 1888, was presented by Dr. H. Hicks, F.R.S., F.G.S.

The President, in accordance with Section XI. Art. 8 of the Bye-Laws, read, for the second time, in relation to the proposed alterations in the Bye-Laws, some proposed emendations to the motion of the Council drafted by the Council and signed by the Chairman, a notice signed by Mr. J. Hopkinson and five other Fellows of the Society, and one signed by Mr. R. Lydekker and sixteen other Fellows of the Society.

The following communications were read:—

1. "On the Subdivisions of the Speeton Clay." By G. W. Lamplugh, Esq. (Communicated by Clement Reid, Esq., F.G.S.)

2. "Notes on the Geology of Madagascar." By the Rev. R. Baron. (Communicated by the Director-General of the Geological Survey.) With an Appendix on some fossils from Madagascar, by R. Bullen Newton, Esq., F.G.S.

3. "Notes on the Petrographical Characters of some Rocks collected in Madagascar by the Rev. R. Baron." By F. H. Hatch, Ph.D., F.G.S.

The following specimens were exhibited:—

Specimens exhibited by G. W. Lamplugh, Esq., the Rev. R. Baron, Dr. F. H. Hatch, F.G.S., and R. B. Newton, Esq., F.G.S., in illustration of their communications.

Lithophysæ in Obsidian from the Yellowstone Park, and Lithophysæ of Bala age from Conway, N. Wales, exhibited by G. A. J. Cole, Esq., F.G.S.

March 20, 1889.

W. T. Blanford, LL.D., F.R.S., President, in the Chair.

Peregrine O. Wilson, Esq., Barberton, Transvaal, South Africa, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "Supplementary Note to a paper on the Rocks of the Atlantic Coast of Canada." By Sir J. W. Dawson, K.C.M.G., F.R.S., F.G.S.

In my paper in the 'Geological Journal' for November, 1888, I have referred (p. 805) to the *Olenellus*-fauna as characterizing the Middle Cambrian. This fauna should, I have now no doubt, from the recently published observations of Walcott and Matthew, be regarded as characteristic of the Upper Member of the Lower Cambrian, that is, below the horizon of *Paradoxides*. From this arises a new view of the physical geography of the period, namely, that the Lower Cambrian was, in America, a period of continental depression, and the Middle Cambrian a period of continental elevation. This leads to the important conclusion that a time of elevation intervened between the Huronian and the early Cambrian, and which may represent the apparent gap between these systems in Eastern America. This new view is so important that I think it deserves a special mention in connexion with the probability that the Huronian and Kewenian beds are of littoral origin.

Discussion.

Dr. Hinde observed that a paper published by Prof. Brögger in 1886*, on the age of the *Olenellus*-zone in North America, had apparently escaped the notice of Sir J. W. Dawson. In it this author pointed out that in Scandinavia, where the succession was unmistakably clear, the *Olenellus*-zone was at the base of the Cambrian, and was succeeded above by the *Paradoxides*-zone, and that the same order of succession would in all probability be likewise found in North America. This prediction had been verified by Mr. Walcott this last summer, and the views hitherto maintained by the American geologists as to the earlier age of the *Paradoxides*-beds are now given up.

Dr. Hicks confirmed the above remarks. Hitherto, in the St. David's district, no definite *Olenellus*-fauna had been discovered, but he believed that the horizon was indicated by the *Lingulella-primæva* zone, which occurs near the base of the Cambrian and several hundred feet below the lowest *Paradoxides*-beds. In Shropshire, on the other hand, the *Olenellus*-fauna had been found, but not that associated with *Paradoxides*.

Mr. Marr felt sure that the *Olenellus*-question would attain to importance before long. Prof. Brögger had determined the true position of the beds with certainty. He believed that the Georgia group contained beds of newer age interfolded with the *Olenellus*-beds.

2. "The Occurrence of Colloid Silica in the Lower Chalk of Berkshire and Wiltshire." By W. Hill, Esq., F.G.S., and A. J. Jukes-Browne, Esq., F.G.S.

3. "Note on the pelvis of *Ornithopsis*." By Prof. H. G. Seeley, F.R.S., F.G.S.

* Geol. För. i Stockh. Förhandl. Bd. viii. p. 182.

Microscopic sections and specimens were exhibited by A. J. Jukes-Browne, Esq., F.G.S., and W. Hill, Esq., F.G.S., in illustration of their paper.

April 3, 1889.

W. T. Blanford, LL.D., F.R.S., President, in the Chair.

Enoch Kidson, Esq., 69 Gregory Boulevard, Nottingham; and Prof. Edward Wadsworth, A.M., Ph.D., Director of the Michigan Mining School, Houghton, Michigan, U.S.A., were elected Fellows; Prof. F. Fouqué, of Paris, and Prof. K. A. von Zittel, of Munich, Foreign Members; and M. Michel-Lévy, of Paris, and Prof. G. K. Gilbert, of Washington, D.C., U.S.A., Foreign Correspondents of the Society.

The List of Donations to the Library was read.

The Secretary announced that the following works, ordered by the Council to be purchased, were on the table:—The Life and Letters of Charles Darwin, 3 vols.; and Borneo, by T. Posewitz.

The President announced that, according to a circular lately received, the "Société Géologique de France" proposed to hold its extraordinary Meeting this year in Paris, the date being fixed for the 18th August next.

The following communications were read:—

1. "The Elvans and Volcanic Rocks of Dartmoor." By R. N. Worth, Esq., F.G.S.

2. "The Basals of Eugeniacrinidæ." By F. A. Bather, Esq., B.A., F.G.S.

3. "On some Bryozoa from the Inferior Oolite of Shipton Gorge, Dorset." By E. A. Walford, Esq., F.G.S.

The following specimens were exhibited:—

Specimens of *Eugeniacrinus caryophyllatus* lent by Prof. K. A. von Zittel, F.M.G.S., and exhibited by F. A. Bather, Esq., F.G.S., in illustration of his paper.

30 slides of Bryozoa from the Inferior Oolite of Dorset, exhibited by E. A. Walford, Esq., F.G.S., in illustration of his paper.

A Special General Meeting was held at 7.30 P.M., before the Ordinary General Meeting, for the purpose of voting upon certain proposed alterations in the Bye-Laws, adjourned from a Special General Meeting on March 15th. In a final ballot the Bye-Laws as amended by the Council were formally adopted.

April 17, 1889.

W. T. Blanford, LL.D., F.R.S., President, in the Chair.

The Rev. R. Baron, F.L.S., The Mission House, Blomfield Street, E.C., and Antananarivo, Madagascar; João Francisco Braga, Esq., F.C.S., Alexandra House, Shepherd's Bush Road, West Kensington Park, W.; Charles A. V. Butler, Esq., Johannesburg, Transvaal, South Africa; Theodore Thomas Groom, Esq., B.Sc. Lond., St. John's College, Cambridge; Prof. John Burchmore Harrison, M.A., F.C.S., Government Laboratory, Bridgetown, Barbadoes; and William Lewis Meredith, Esq., 7 Midland Road, Gloucester, were elected Fellows of the Society.

The List of Donations to the Library was read.

The President, in accordance with Section XI. Art. 8 of the Bye-Laws, read for the first time some proposed verbal alterations in the Bye-Laws as amended, signed by the Chairman of the Council.

The following communications were read:—

1. "On the Production of Secondary Minerals at Shear-zones in the Crystalline Rocks of the Malvern Hills." By Charles Callaway, Esq., M.A., D.Sc., F.G.S.

2. "The Northern Slopes of Cader Idris." By Grenville A. J. Cole, Esq., F.G.S., and A. V. Jennings, Esq., F.L.S.

The following specimens were exhibited:—

Rock-specimens and microscopic sections exhibited by Charles Callaway, D.Sc., F.G.S., in illustration of his paper.

Rock-specimens, microscopic sections, and photographs exhibited by Messrs. Grenville A. J. Cole, F.G.S., and A. V. Jennings, F.L.S., in illustration of their paper.

Specimens of *Gastornis Klaasseni*, recently found in the Woolwich Beds, near Croydon, by H. M. Klaassen, Esq., F.G.S., exhibited by E. T. Newton, Esq., F.G.S.

May 8, 1889.

W. T. Blanford, LL.D., F.R.S., President, in the Chair.

The List of Donations to the Library was read.

The President, in accordance with Section XI. Art. 8 of the Bye-Laws, read for the second time some proposed verbal alterations in the Bye-Laws as amended, signed by the Chairman of the Council.

The following communications were read:—

1. "The Rocks of Alderney and the Casquets." By the Rev. Edwin Hill, M.A., F.G.S.

2. "On the Ashprington Volcanic Series of South Devon." By the late Arthur Champernowne, Esq., M.A., F.G.S. (Communicated by Dr. A. Geikie, F.R.S., F.G.S.)

The following specimens were exhibited:—

Specimens and microscopic sections of Alderney Rocks, exhibited by the Rev. Edwin Hill, F.G.S., in illustration of his paper.

Specimens illustrating the paper by the late A. Champernowne, Esq., F.G.S., exhibited by Dr. A. Geikie, F.R.S., F.G.S.

May 22, 1889.

W. T. Blanford, LL.D., F.R.S., President, in the Chair.

James Berry, Esq., M.B., B.Sc. Lond., F.R.C.S., 60 Welbeck Street, Cavendish Square, W.; Arthur Richard Browne, Esq., care of Lord Richard Browne, Reigate; and William Fraser Hume, Esq., Assoc. Normal School of Science, 27 Ella Road, Crouch Hill, N., were elected Fellows of the Society.

The List of Donations to the Library was read.

The names of certain Fellows were read out for the first time in conformity with the Bye-Laws, Section VI. Art. 5, in consequence of the non-payment of their arrears of contributions.

The following communications were read:—

1. "Notes on the Hornblende Schists and Banded Crystalline Rocks of the Lizard." By Major-Gen. C. A. McMahon, F.G.S.

2. "The Upper Jurassic Clays of Lincolnshire." By Thomas Roberts, Esq., M.A., F.G.S.

3. "Origin of Movements in the Earth's Crust." By James R. Kilroe, Esq. (Communicated by A. B. Wynne, Esq., F.G.S.)

[Abstract.]

The Author is convinced that a very important factor has been omitted from the usual explanation offered in accounting for the vast movements which have obtained in the Earth's crust. His acknowledgments are due to Mr. Fisher for the extensive use made of his valuable work. He also refers frequently to the views and publications of other writers on terrestrial physics. From a somewhat conflicting mass of figures he concludes that about 20 miles would remain to represent the amount of radial contraction due to cooling during the period from Archæan to Recent times, corresponding to a circumferential contraction of 120 miles. This will have to be distributed over widely separate periods, at each of which there is abundant evidence of lateral compression.

But he considers that this shrinkage alone will not account for all the plication or distortion of strata which constitute so important a

factor in mountain-making, and he is disposed to supplement it in the way to which allusion has already been made by Mr. Wynne in a recent Presidential Address, viz. by considering the effects of the attenuation of strata under superincumbent pressure from deposition in subsiding areas, which involves the thickening, puckering, reduplication, and piling up of strata in regions where pressure has been lessened. It should be noted that, until disturbance of "cosmical equilibrium" takes place, mere pressure does not produce metamorphism. The extent of these lateral movements is described, and it is asserted that the theories hitherto adopted to account for plication, &c. are inadequate.

The origin of the horizontal movements is further discussed on the hypothesis that solids can flow after the manner of liquids, when they are subjected to sufficient pressure. He considers that the displacement in N.W. Scotland may have been *initiated* by the force due to contraction, and accumulating in the crust throughout the periods marked by the deposition of Torridon Sandstone and Silurian strata, the elements of movement finding an exit at the ancient Silurian surface. In this case the pile of Silurian strata formerly covering the region now occupied by the North Sea and part of the Atlantic forced the lowest strata to move laterally, the protuberances of the underlying pre-Silurian rocks being also involved in the shearing process. Similar results in other mountain areas. The strata compressed have been greatly attenuated and extended in proportion; in this way we may account for the piling up of strata by contortion in certain regions. The connexion of this interpretation with Mallet's theory of volcanoes is also indicated, and the Author concludes by applying these views to other branches of terrestrial physics.

Discussion.

The President observed that Mr. Wynne, in his recent address, had acknowledged his indebtedness to Mr. Kilroe. He himself regarded the subject as well worthy of consideration, for he had long felt convinced that the theory of contraction alone was insufficient to account for all the phenomena of movement in the earth's crust.

The following specimens were exhibited:—

Rocks and microscopic sections, exhibited by Major-Gen. C. A. McMahon, F.G.S., in illustration of his paper.

Specimens of Jurassic fossils exhibited by Thomas Roberts, Esq., F.G.S., in illustration of his paper.

Specimens of Hornblende Schist and Gneiss from Sark, exhibited by Prof. T. G. Bonney, F.R.S., F.G.S.

Specimens illustrating the effect of deforming heterogeneous masses of Clay, exhibited by J. J. H. Teall, Esq., F.G.S.

Specimen of Banded Serpentine from the Lizard, exhibited by Sir Warington W. Smyth, F.R.S., F.G.S.

Specimens and photographs of Fossil Siliceous Sponges from the Quebec Group (Ordovician) of Little Métis, Lower St. Lawrence, exhibited by Dr. George J. Hinde, F.G.S., on behalf of Sir J. W.

Dawson, F.R.S., F.G.S. Dr. Hinde stated that these sponges in many instances retained their outlines and their spicular structure, now pyritized, in beautiful preservation. They belong to *Protospongia* and other allied genera of Lyssacine Hexactinellids, and like their existing descendants possess tufts of long anchoring spicules. They occur in great abundance at Métis in black shales, some beds being filled with their spicular remains.

A Special General Meeting was held at 7.45 P.M., before the Ordinary General Meeting, for the purpose of voting upon certain proposed verbal alterations in the amended Bye-Laws. The suggested alterations were Balloted for and carried.

June 5, 1889.

Prof. J. W. Judd, F.R.S., Vice-President, in the Chair.

Major Edwin Parkyn, J.P., 40 Lemon Street, Truro, Cornwall, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following names of Fellows were read out for the second time in conformity with the Bye-Laws, Section VI. Art. 5, in consequence of the non-payment of their arrears of contributions:—E. Brunt, Esq., H. S. Holme, Esq., G. T. Parnell, Esq.

The Chairman announced that it is proposed by the Geologists' Association to organize a Geological Excursion to the Volcanic Regions of Italy—Naples, Rome, Sicily, and the Lipari Islands, or to some of these places if not to all of them—during the month of October next.

The following communications were read:—

1. "Observations on some undescribed Lacustrine Deposits at Saint Cross, South Elmham, in Suffolk." By Charles Candler, Esq. (Communicated by Clement Reid, Esq., F.G.S.)

2. "On certain Chelonian Remains from the Wealden and Purbeck." By R. Lydekker, Esq., B.A., F.G.S.

3. "On the Relation of the Westleton Beds or Pebbly Sands of Suffolk to those of Norfolk, and on their Extension inland; with some Observations on the Period of the final Elevation and Denudation of the Weald and of the Thames Valley." By Prof. Joseph Prestwich, M.A., D.C.L., F.R.S.—Part I.

Specimens of fossil seeds and Mollusca were exhibited by Clement Reid, Esq., F.G.S., in illustration of the paper by Charles Candler, Esq.

June 19, 1889.

Prof. J. W. Judd, F.R.S., Vice-President, in the Chair.

Lieut.-Colonel Birkett, Natal Royal Rifles, Natal; Joseph Edmund Carne, Esq., Geological Museum, Department of Mines, Sydney, N.S.W.; John Sydney Crawford, Esq., care of W. R. Kerr, Esq., 8 Nevill Terrace, Onslow Gardens, S.W., and James Thomas Day, Esq., 12 Albert Square, Stepney, E., were elected Fellows, and Prof. A. Stoppani, Florence, and M. R. D. M. Verbeek, Java, Foreign Correspondents of the Society.

The List of Donations to the Library was read.

The Secretary announced that 14 specimens from the De Kaap Gold Fields, South African Republic, had been presented by R. H. Scaddan, Esq., of Johannesburg.

The following communications were read:—

1. "On Tachylyte from Victoria Park, Whiteinch, neer Glasgow." By Frank Rutley, Esq., F.G.S.

2. "The Descent of *Sonninia* and *Hammatoceras*." By S. S. Buckman, Esq., F.G.S.

3. "Notes on the Bagshot Beds and their Stratigraphy." By H. G. Lyons, Esq., R.E., F.G.S.

4. "Description of some new Species of Carboniferous Gasteropoda." By Miss Jane Donald. (Communicated by J. G. Goodchild, Esq., F.G.S.)

5. "*Cystechinus crassus*, a new Species from the Radiolarian Marls of Barbadoes; and the evidence it affords as to the Age and Origin of those Deposits" By J. W. Gregory, Esq., F.G.S.

The following specimens were exhibited:—

Specimens exhibited by Frank Rutley, Esq., F.G.S., in illustration of his paper.

Specimens of *Sonninia* and *Hammatoceras*, exhibited by S. S. Buckman, Esq., in illustration of his paper.

Microscopic section of the Radiolarian-Marl matrix of *Cystechinus crassus* from Barbadoes, exhibited by J. W. Gregory, Esq., F.G.S., in illustration of his paper.

A Collotype view of Fossil Trees, Victoria Park, Whiteinch, Glasgow, exhibited by S. H. Needham, Esq., F.G.S.

ADDITIONS

TO THE

LIBRARY AND MUSEUM OF THE GEOLOGICAL SOCIETY.

Session 1888–89.

I. ADDITIONS TO THE LIBRARY.

1. Periodicals and Publications of Learned Societies.

Presented by the respective Societies and Editors, if not otherwise stated.

Academy. Nos. 842-869. 1888.

——. Nos. 870–893. 1889.

Adelaide. Royal Society of South Australia. Transactions and Proceedings and Report. Vol. x. (For 1886–87.) 1888.

W. Howchin. Remarks on a Geological Section at the New Graving Dock, Glanville, with special reference to a supposed Old Land Surface now below Sea-level, 31.—W. L. Cleland. Caroona Hill (Lake Gilles), 74.—H. Y. L. Brown. Notes on the Geological Features of the Teetulpa Goldfields, 82.—R. Tate. The Gastropods of the Older Tertiary of Australia, Part I., 91.

Analyst. Vol. xiii. Nos. 147–152. 1888.

——. Vol. xiv. Nos. 153–158. 1889.

Annals and Magazine of Natural History. Ser. 6. Vol. ii. Nos. 7–12. 1888. *Purchased.*

R. Kidston. On the Fructification of two Coal-measure Ferns, 22.—H. J. Carter. On the Organic and Inorganic Changes of *Parkeria*, together with further observations on the Nature of the Opaque Scarlet Spherules in Foraminifera, 45.—R. Kidston. On a new Species of Calamites from the Middle Coal-measures (*Eucalamites* (*Calamites*) *britannicus*, Weiss, MS.), 129.—A. Smith Woodward. Notes on some Vertebrate Fossils from the Province of Bahia, Brazil, collected by Joseph Mawson, Esq., 132.—A. Smith Woodward. On the Fossil Fish-spines named *Cœlorhynchus*, Agassiz, 223.—T. Rupert Jones. Notes on the Palæozoic Bivalved Entomostraca, No. XXVI. On some new Devonian Ostracoda, with a Note on their Geological Position by the Rev. G. F. Whidborne, 295.—J. Thomson. On a new Species of *Diphyphyllum*, and

on a remarkable Form of the Genus *Lithostrotion*, 317.—P. Martin Duncan and W. Percy Sladen. Objections to the Genera *Pseudopygaulus*, Coquand, *Trachyaster*, Pomel, and *Ditremaster*, Munier-Chalmas: their Species restored to *Eolampas*, Dunc. and Sladen, and *Hemiaster*, Desor, 327.—A. Smith Woodward. On some Remains of the Extinct Selachian *Asteracanthus* from the Oxford Clay of Peterborough, preserved in the Collection of Alfred N. Leeds, Esq., 336.—A. Smith Woodward. A Comparison of the Cretaceous Fish-fauna of Mount Lebanon with that of the English Chalk, 354.—A. Smith Woodward. On *Bucklandium diluvii*, König, a Siluroid Fish from the London Clay of Sheppey, 355.—H. C. McCook. A new Fossil Spider (*Eoatypus Woodwardii*), 366.—H. J. Carter. On the Foraminiferal Genus *Orbitoides* of d'Orbigny, 439.

Annals and Magazine of Natural History. Ser. 6. Vol. iii. Nos. 13–18. 1889. *Purchased.*

R. Lydekker. Preliminary Notice of new Fossil Chelonia, 53.—G. Baur. The Systematic Position of *Meiolania*, Owen, 54.—R. Lydekker. *Nototherium* and *Zygomaturus*, 149.—P. M. Duncan. On some Points in the Anatomy of *Palæechinus* (Scouler), M'Coy, and a proposed Classification, 196.—H. J. Carter. Further Observations on the Foraminiferal Genus *Orbitoides* of d'Orbigny, 210.—G. Baur. On "*Aulacochelys*," Lydekker, and the Systematic Position of *Anosteira*, Leidy, and *Pseudotrionyx*, 273.—A. Smith Woodward. Palæichthyological Notes, 297.—T. Rupert Jones. Notes on the Palæozoic Bivalved Entomostraca, No. XXVII. On some North-American (Canadian) species, 373.—J. W. Gregory. On *Zeuglopleurus*, a new Genus of the Family Temnopleuridæ from the Upper Cretaceous, 490.

Army Medical Department. Report for the year 1886. Vol. xxviii. 1888.

Athenæum (Journal). Nos. 3165–3192. 1888.

——. Nos. 3193–3216. 1889.

——. Parts 725–732. 1888.

——. Parts 733–737. 1889.

Ballarat School of Mines, Industries, and Science. Annual Report, 1888. 1889.

Baltimore. Maryland Academy of Sciences. Transactions. 1888. Vol. i. pp. 1–24. 1888.

P. R. Uhler. Observations on the Eocene Tertiary and its Cretaceous Associates in the State of Maryland, 11.

Barnsley. Midland Institute of Mining, Civil, and Mechanical Engineers. Transactions. Vol. xi. Parts 96–102. 1888–89.

Basel. Société Paléontologique Suisse. Mémoires. Vol. xv. 1888. 1888. *Purchased.*

L. Rütimeyer. Beziehungen zwischen Säugethierstämmen Alter und Neuer Welt.—F. Koby. Monographie des polypiers jurassiques de la Suisse, 8e partie.—E. Greppin. Description des fossiles de la grande Oolithe des environs de Bâle.—P. de Loriol et l'Abbé Bourgeat. Etudes sur les mollusques des couches coralligènes de Valfin, 3e partie.

Bath Natural-History and Antiquarian Field Club. Proceedings. Vol. vi. No. 4. 1889.

Belfast Natural-History and Philosophical Society. Report and Proceedings for 1887–88. 1888.

—— Naturalists' Field Club. Annual Report and Proceedings. 1887–88. Series 2. Vol. iii. Part 1. 1888.

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